



Biological Psychology

M5X00908 Brain, Behaviour, and Cognition (BBC)

Lecture 1: Anatomy of the Nervous System

Dr Kate Williams

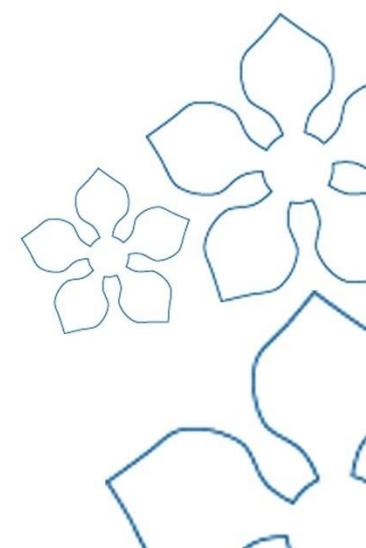


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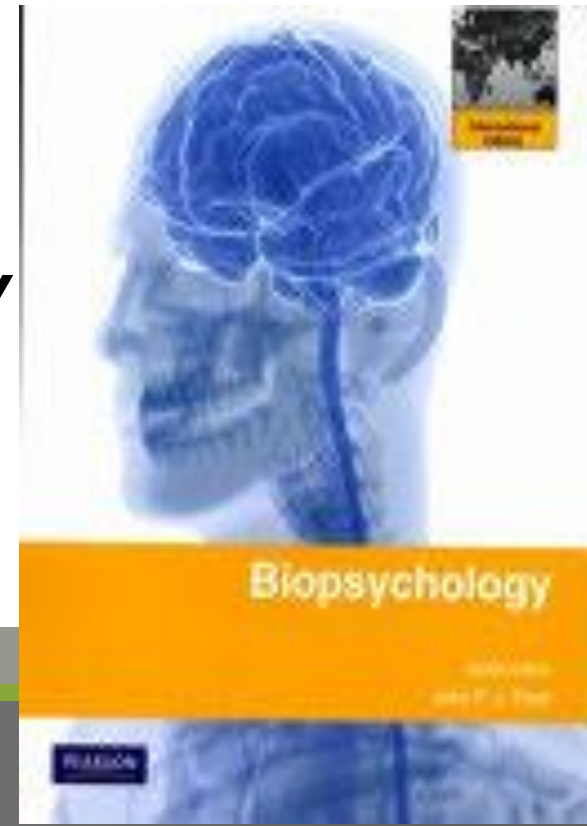


Structure of Lectures and Seminars



Biological Psychology:

- **Lecture:** 2 hours – Wed 9am-11am
 - 15 minute break/5 minute breaks throughout lecture
- **Seminar:** 1 hour – Thur 1-2pm
- **CORE TEXT:**
- **Pinel, J.P.J (2014). *Biopsychology***
 - *Library catalogue number:*
 - **612.8 PIN**
 - *Available as e-book.*

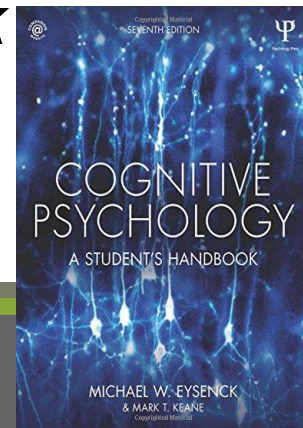


Structure of Lectures and Seminars



Cognitive Psychology:

- **Lecture:** 1 hour - Thur 10-11am
- **Seminar:** 1 hour – Thur:
 - Group 1: 11am-12pm & Group 2: 12-1pm
 - (check timetable for group allocation)
 - **NOTE:** Some weeks all students are expected to attend the seminar together from 11am-1pm: **See weekly planner.**
- **CORE TEXT = Eysenck, M. W., & Keane, M. T. (2015). *Cognitive psychology: A student's handbook***
- ***Library catalogue number = 153.EYS***
 - ***Available as e-book***



Structure of Assessments



Cognitive Psychology:

- 1 x ONE hour exam (25% of overall module mark).
 - Answer ONE question from a choice of four.
- 1 x 1,250 word essay (25% of overall module mark).

Biological Psychology:

1 x TWO hour exam (50% of overall module mark)

Exam is divided in to three Sections:

Section A: Answer 2 Qs from 6 (Each Q is worth 5 marks)

Section B: Answer 2 Qs from 6 (Each Q is worth 10 marks)

Section C: Answer 2 Qs from 6 (Each Q is worth 35 marks)

3

ANATOMY OF THE NERVOUS SYSTEM

SYSTEMS, STRUCTURES, AND CELLS THAT MAKE UP YOUR NERVOUS SYSTEM

Based on the Power Point Lecture Slides prepared by Jeffrey W. Grimm, Western Washington University

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BIOPSYCHOLOGY 8e

John P.J. Pinel

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Why study biology?



- **Most important structure controlling behavior = brain.**
- **Every mental process has physical or neural basis.**
- **Thus, we need to understand how the brain works.**
- **Biological Ψ built on idea that the mind is the product of the brain's electrical and neurochemical activity.**
- **First, we need to understand the anatomy of the brain**
 - **What it is and how it is structured.**

Why study biology?



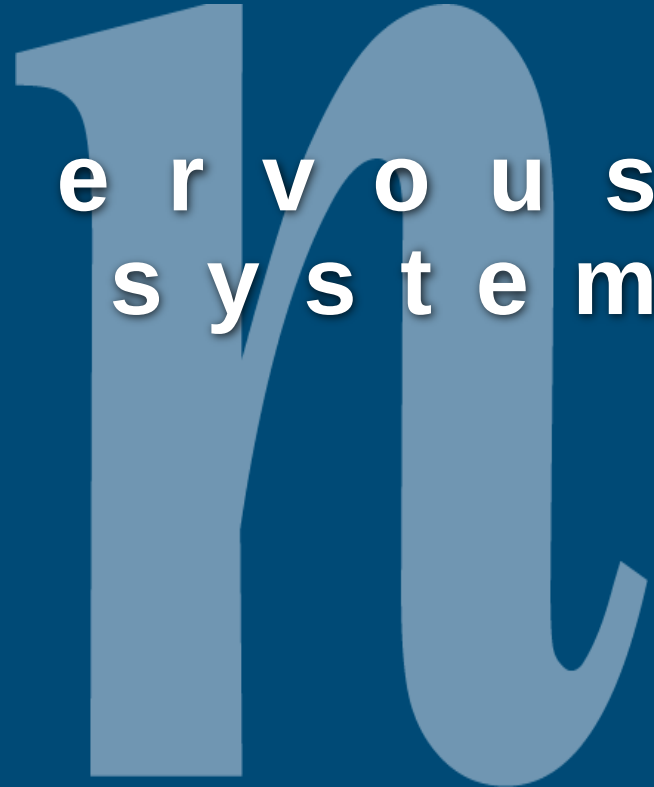
- **Today's lecture:**
 - **Examine layout of nervous system, cells, neuroanatomical techniques and directions, spinal cord, major divisions of the brain, and major structures of the brain**
 - **Chapter 3 Biopsychology by Pinel.**
 - **Axon growth and synapse formation, neuron death and synapse rearrangement, postnatal cerebral developments, neural circuits and neuroplasticity in adults.**
 - **Chapter 9 Biopsychology by Pinel.**



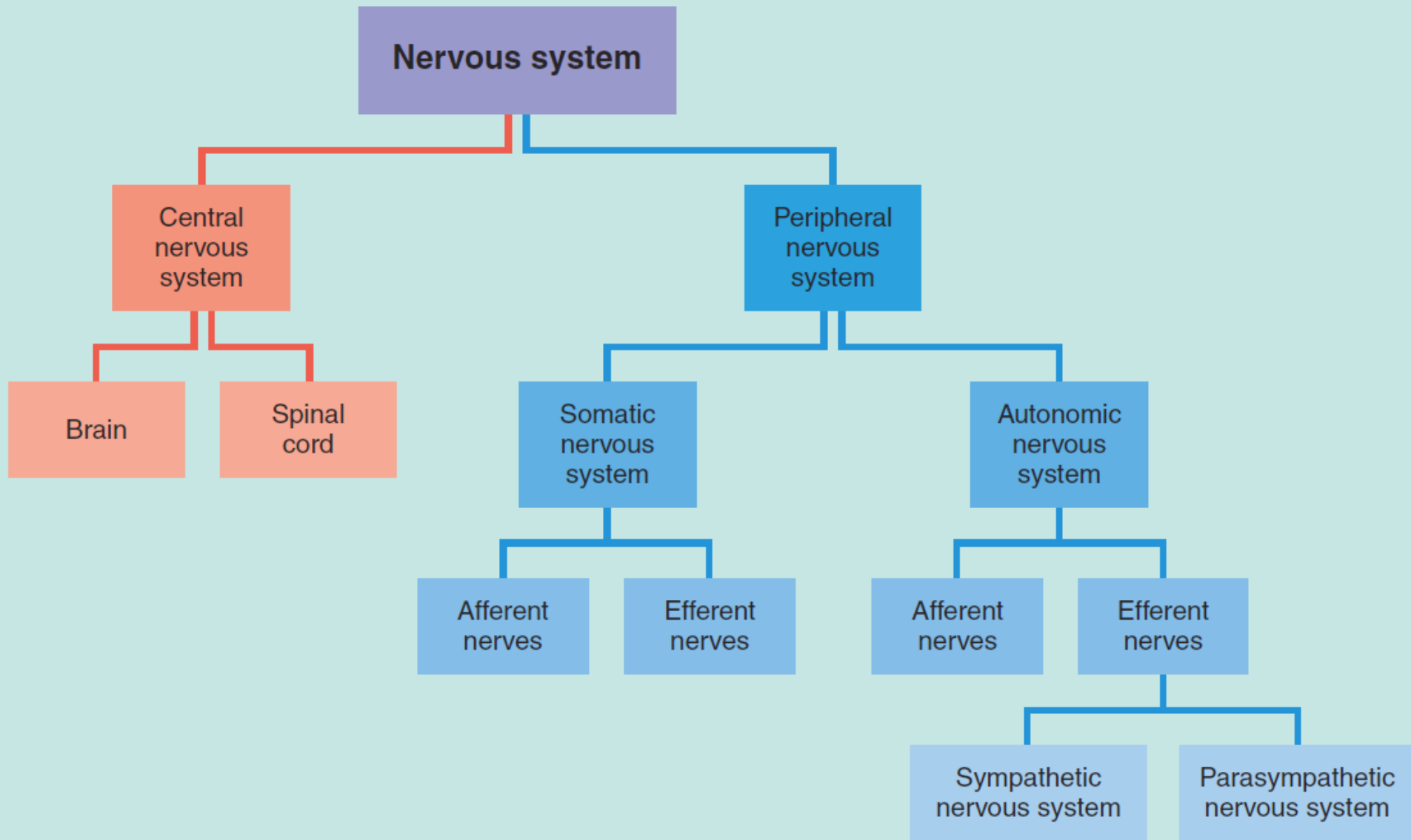
A communication network consisting of nerve cells, both inside and outside of the brain and spinal cord.

It transmits nerve impulses between parts of the body.

**e r v o u s
s y s t e m**



General Layout of the Nervous System



Major divisions of the nervous system.

General Layout of the Nervous System

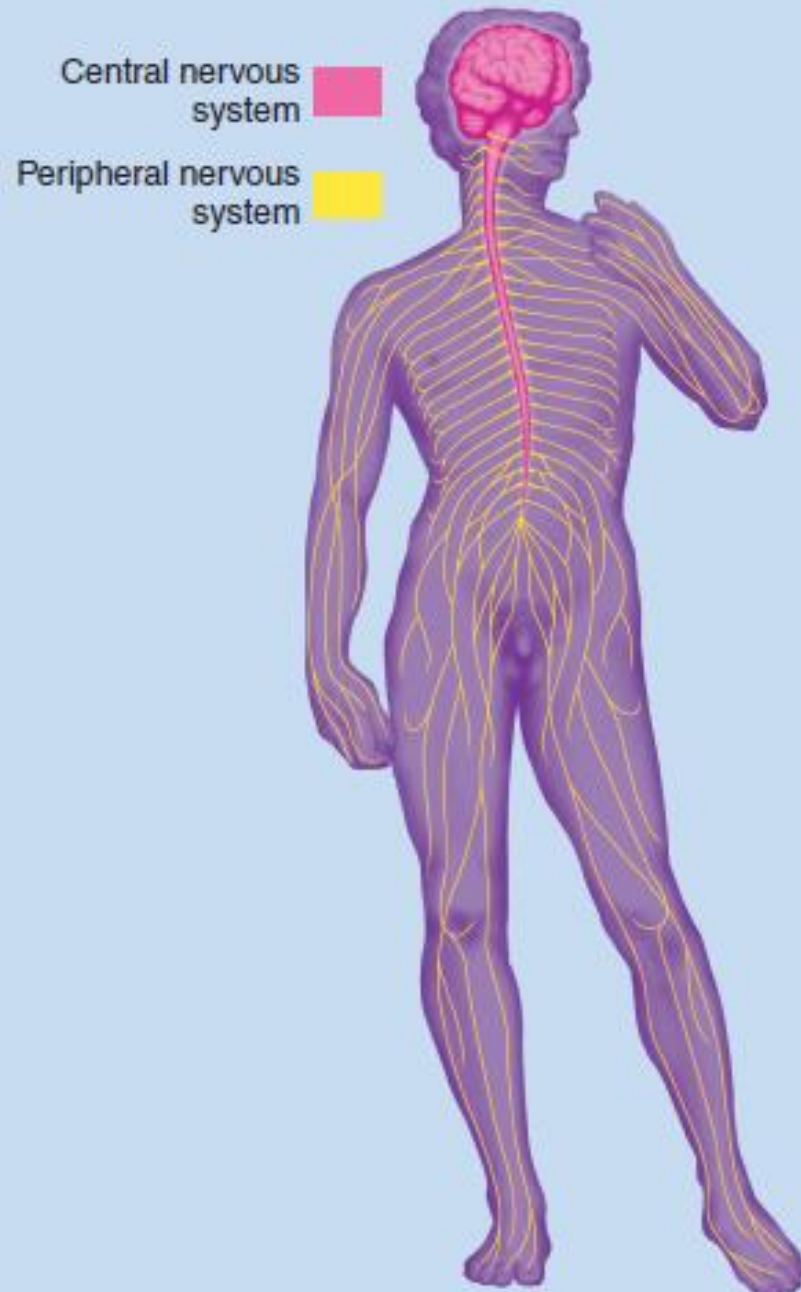


Central Nervous System (CNS)

- Brain (in the skull)
- Spinal Cord (in the spine)

Peripheral Nervous System (PNS)

- Located outside the skull and spine
- Serves to bring information into the CNS and carry signals out of the CNS

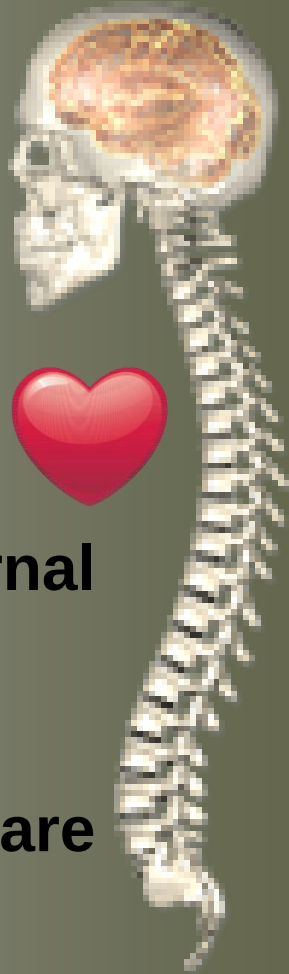


General Layout of the Nervous System



Peripheral Nervous System (PNS) – Function of the sub-divisions

- **Somatic Nervous System (SNS)** – interacts with external environment and made-up of:
 - Afferent nerves (carry sensory signals)
 - Efferent nerves (carry motor signals)
- **Autonomic Nervous System (ANS)** – regulates internal body environment
 - Afferent nerves (sensory info from organs)
 - Efferent nerves (motor info to organs) which are
 - Sympathetic and parasympathetic nerves



Autonomic Nervous System



- **Sympathetic and parasympathetic nerves are known as Two-stage neural paths:**
 - They project from CNS but only go some of the way
 - The neuron exiting the CNS synapses on a second-stage neuron before reaching the target organ.
- Neurons in SNS synapse on 2nd-stage neurons at a long distance away from the organ they intend to travel.
- Neurons in PSS synapse close to the target organ on a very short 2nd-stage neuron.

See Appendix 1 in Pinel book.

Autonomic Nervous System



SNS & PSS nerves have opposite effects.

SYMPATHETIC

Project from CNS in Thoracic (chest) and lumbar (bottom of back) areas of spinal cord.

“Fight or flight”: stimulate, organize, & mobilize energy resources when in threat.

Second stage neurons are far from the target organ

PARASYMPATHETIC

Project from the Cranial (brain) and sacral (lower back area of spinal cord).

“Rest and restore”: conserve energy

Second stage neurons are near the target organ

See Appendix 2 in Pinel book



How is the brain protected?



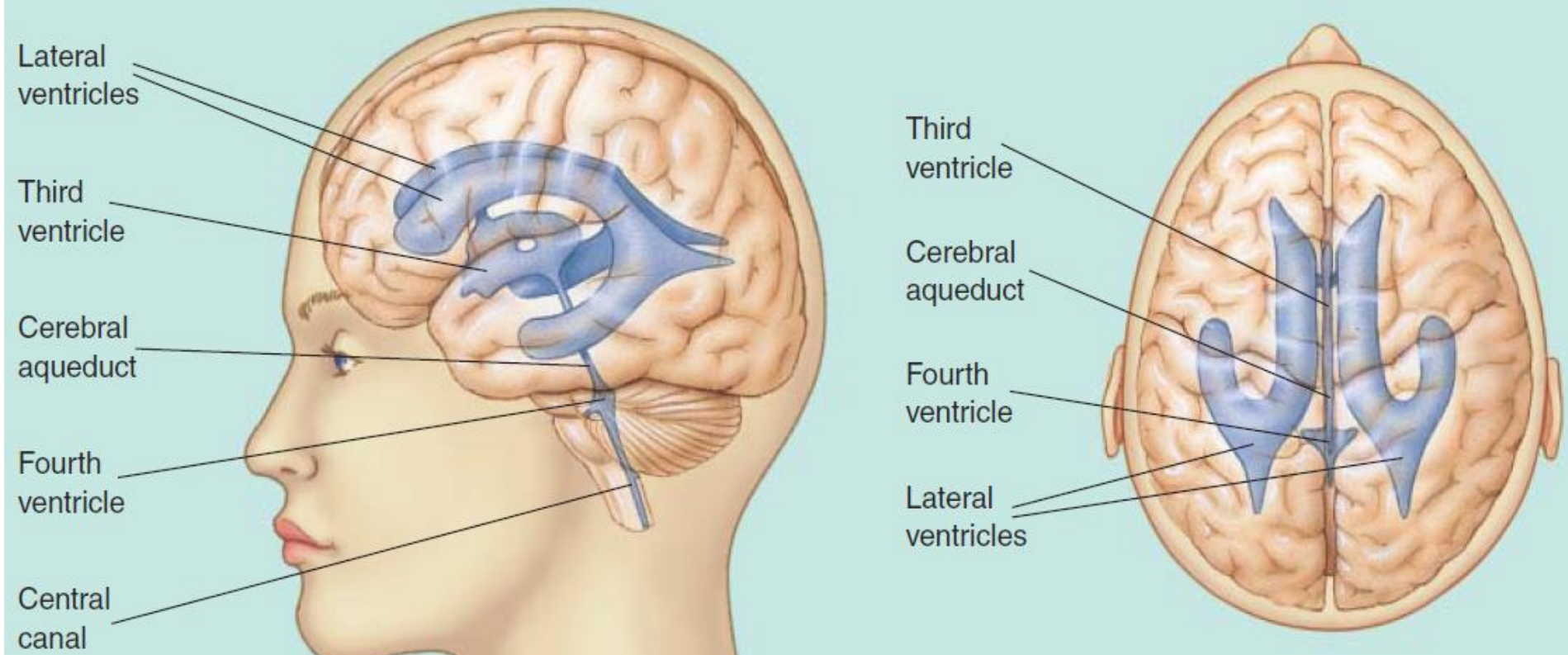
Physical Protection

- **Skull – CNS encased in bone & covered by:**
- **3 Meninges**
 - **Dura mater – tough outer membrane**
 - **Arachnoid membrane – quite fine & web-like**
 - **Pia mater – inner & delicate membrane that adheres to CNS surface**
- **Cerebrospinal fluid (CSF) - serves as cushion by filling space underneath arachnoid membrane, central canal of the spinal cord, and cerebral ventricles of the brain.**

The Cerebral Ventricles



4 large internal chambers of the brain



Ventricles, subarachnoid space, & central canal interconnect by series of openings to form a single reservoir.

Body continuously produces CF by the choroid plexuses (network of small blood vessels) that stick to ventricles from the pia matter.

How is the brain protected?



Chemical protection

- **Blood-brain barrier:**
 - Blood contains many toxins, thus the body must stop these passing in to the brain.
 - Cells of blood vessel walls in the brain are tightly packed together to form a barrier stopping molecules passing through.

Effectiveness of medicinal and illegal drugs are measured by how well they can penetrate the blood-brain barrier



Neurons and the Human Brain



- **How does the brain work?**
- **Anatomy of neurons:**
 - Cells that receive and transmit electrochemical signals.
 - Roughly 100 billion neurons arranged in complex array of around 100 trillion connections.

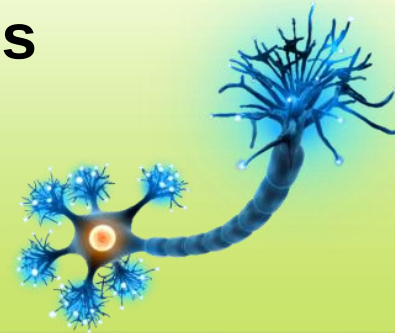
The human brain

An amazingly intricate network of neurons



Neurons

Cells that receive and transmit electrochemical signals



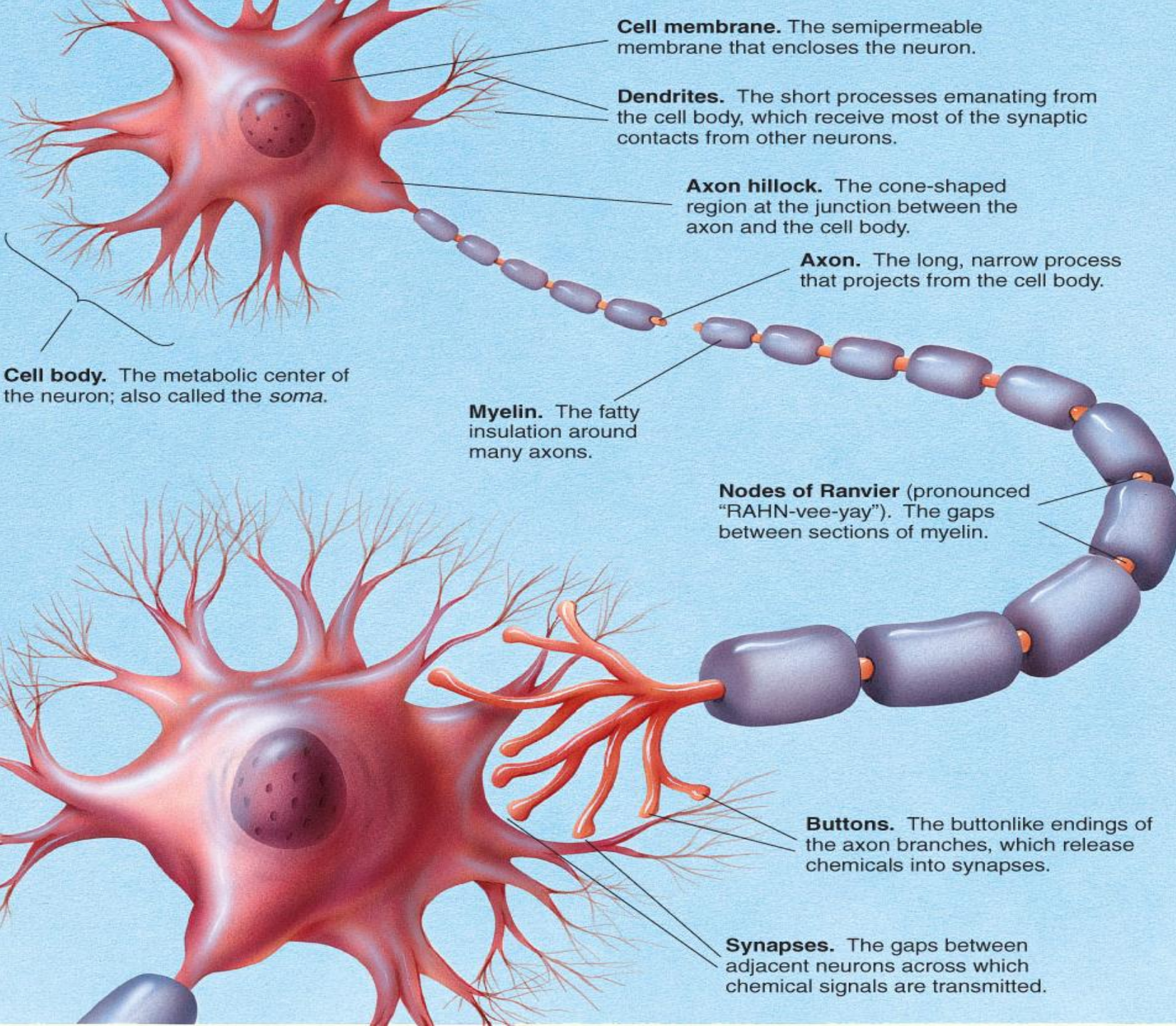
Cells of the Nervous System: Anatomy of Neurons



Neurons:

Specialised cells for the reception, conduction, and transmission of electrochemical signals

Many sizes and shapes but many of them are typically structured



Cell membrane. The semipermeable membrane that encloses the neuron.

Dendrites. The short processes emanating from the cell body, which receive most of the synaptic contacts from other neurons.

Axon hillock. The cone-shaped region at the junction between the axon and the cell body.

Axon. The long, narrow process that projects from the cell body.

Myelin. The fatty insulation around many axons.

Nodes of Ranvier (pronounced "RAHN-vee-yay"). The gaps between sections of myelin.

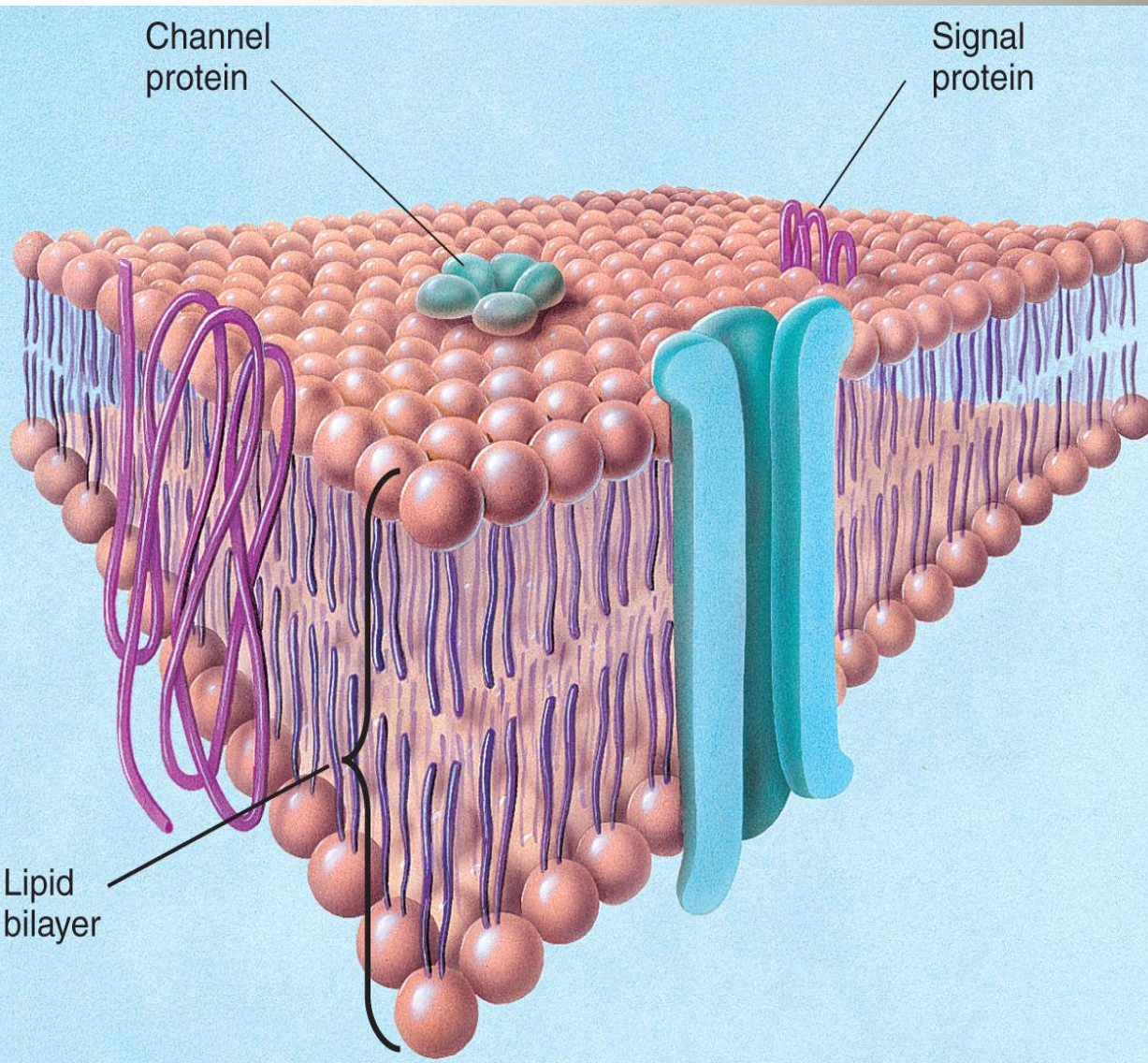
Buttons. The buttonlike endings of the axon branches, which release chemicals into synapses.

Synapses. The gaps between adjacent neurons across which chemical signals are transmitted.



**Major
external
features
of typical
neuron**

Cells of the Nervous System: Anatomy of Neurons



Cell membrane is a lipid (fat molecule) bilayer.

Channel proteins allow certain molecules to pass

Signal proteins transfer signal to the inside of the neuron when certain molecules bind to them on the outside of the membrane.

Cell membrane is semi-permeable.

Major internal features of typical neuron

Endoplasmic reticulum. A system of folded membranes in the cell body; rough portions (those with ribosomes) play a role in the synthesis of proteins; smooth portions (those without ribosomes) play a role in the synthesis of fats.

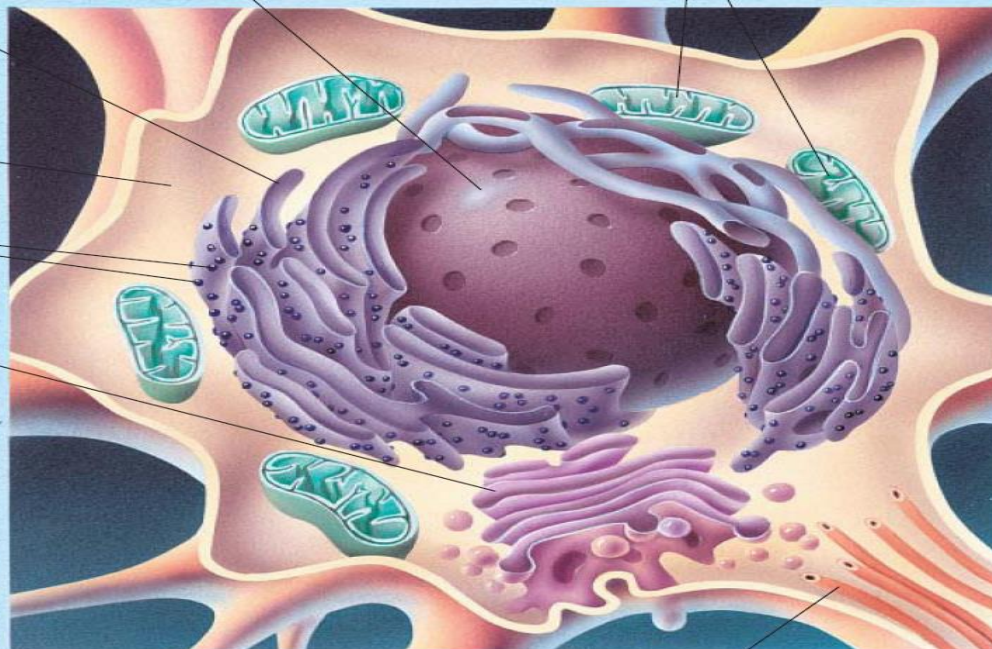
Cytoplasm. The clear internal fluid of the cell.

Ribosomes. Internal cellular structures on which proteins are synthesized; they are located on the endoplasmic reticulum.

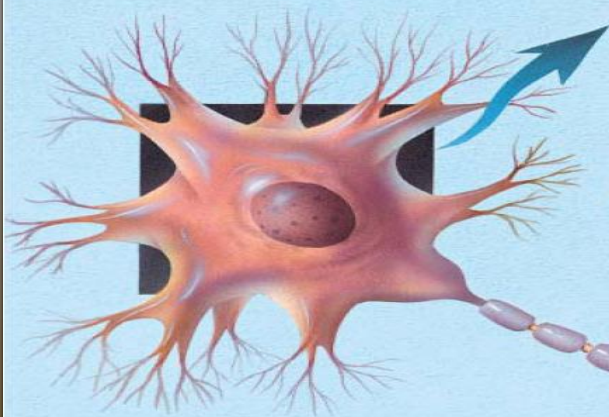
Golgi complex. A connected system of membranes that packages molecules in vesicles.

Nucleus. The spherical DNA-containing structure of the cell body.

Mitochondria. Sites of aerobic (oxygen-consuming) energy release.

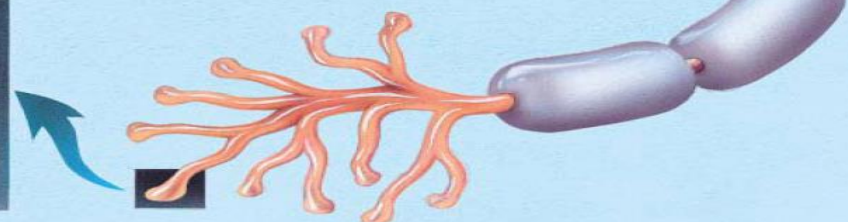
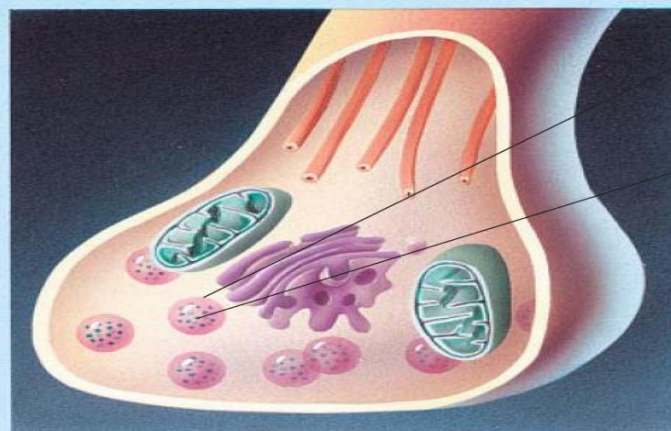


Microtubules. Tubules responsible for the rapid transport of material throughout neurons.



Synaptic vesicles. Spherical membrane packages that store neurotransmitter molecules ready for release near synapses.

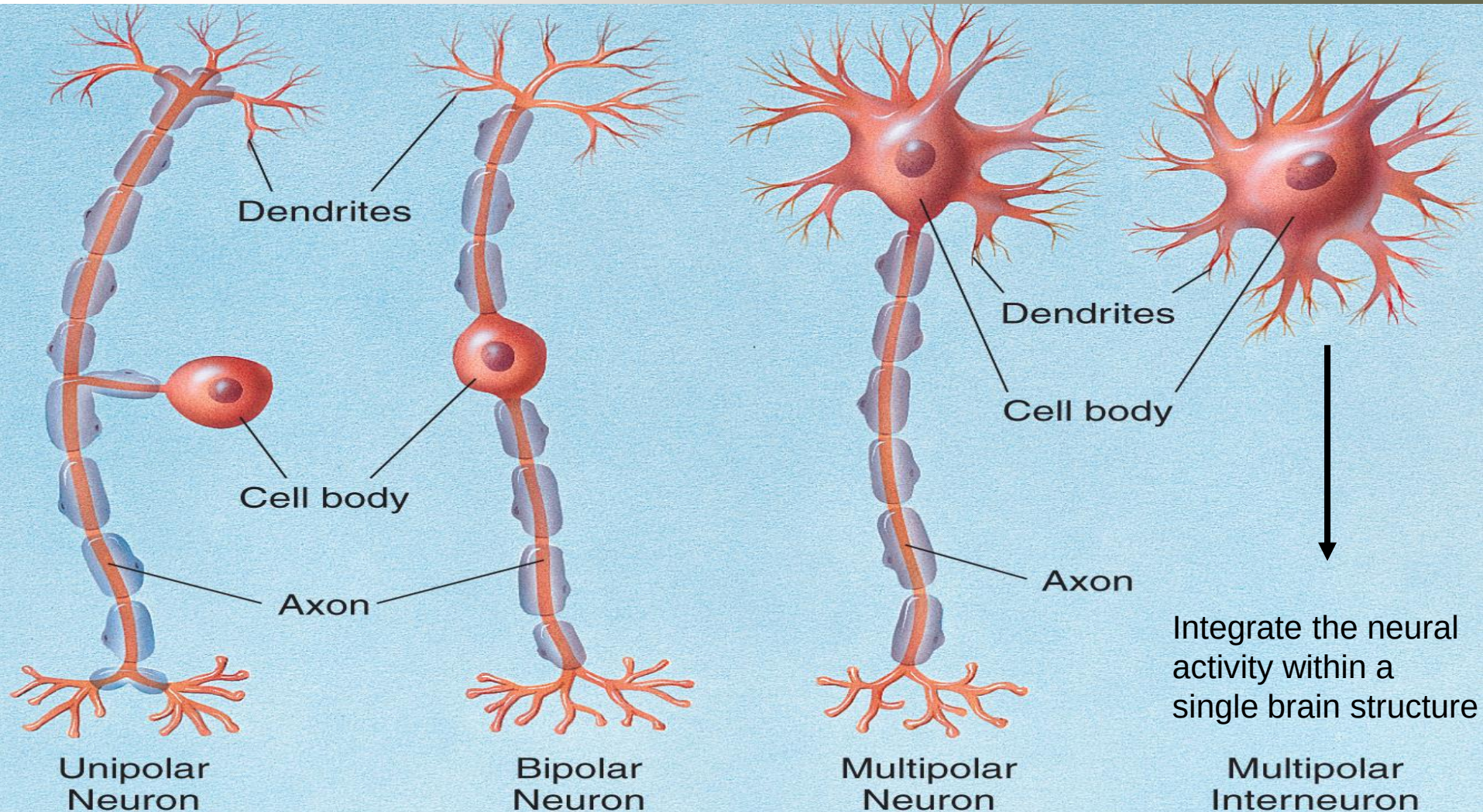
Neurotransmitters. Molecules that are released from active neurons and influence the activity of other cells.



Cells of the Nervous System: Anatomy of Neurons



Different classes of neurons based on no. of projections (processes) that come out of the cell body.



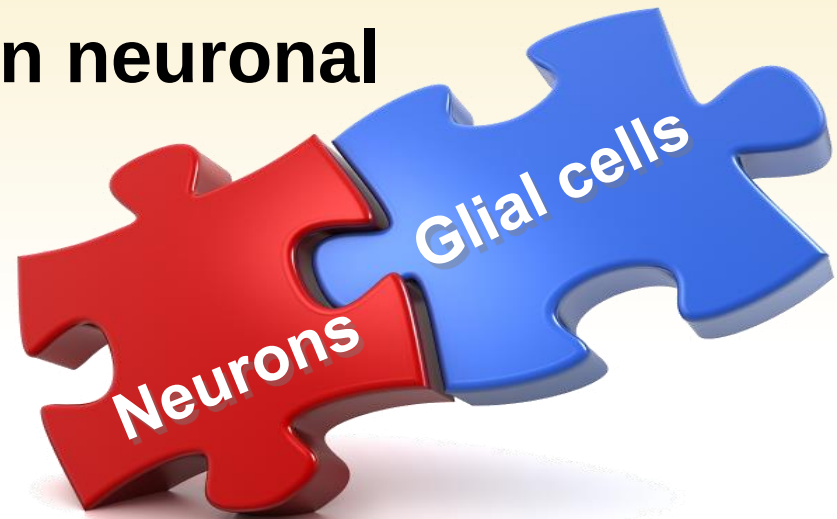
Glial Cells: The Forgotten Cells



Along with neurons, the system is also made-up of glial cells.

Glial cells

- **Support neurons**
- **Recent evidence for glial communication role and modulatory effects of glia on neuronal communication**



Four Classes of Glial Cells



1

Oligodendrocytes: extensions that wrap around axons rich in myelin to create myelin sheaths in CNS to increase speed & efficiency of conduction.

2

Schwann cells – similar to function of oligodendrocytes but in PNS, can guide axonal regeneration

3

Astrocytes: largest, star-shaped, extensions of some cover outer surface of blood vessels in brain, can make contact with neural cell bodies, play role in allowing passage of some chemicals from blood & into central nervous system neurons.

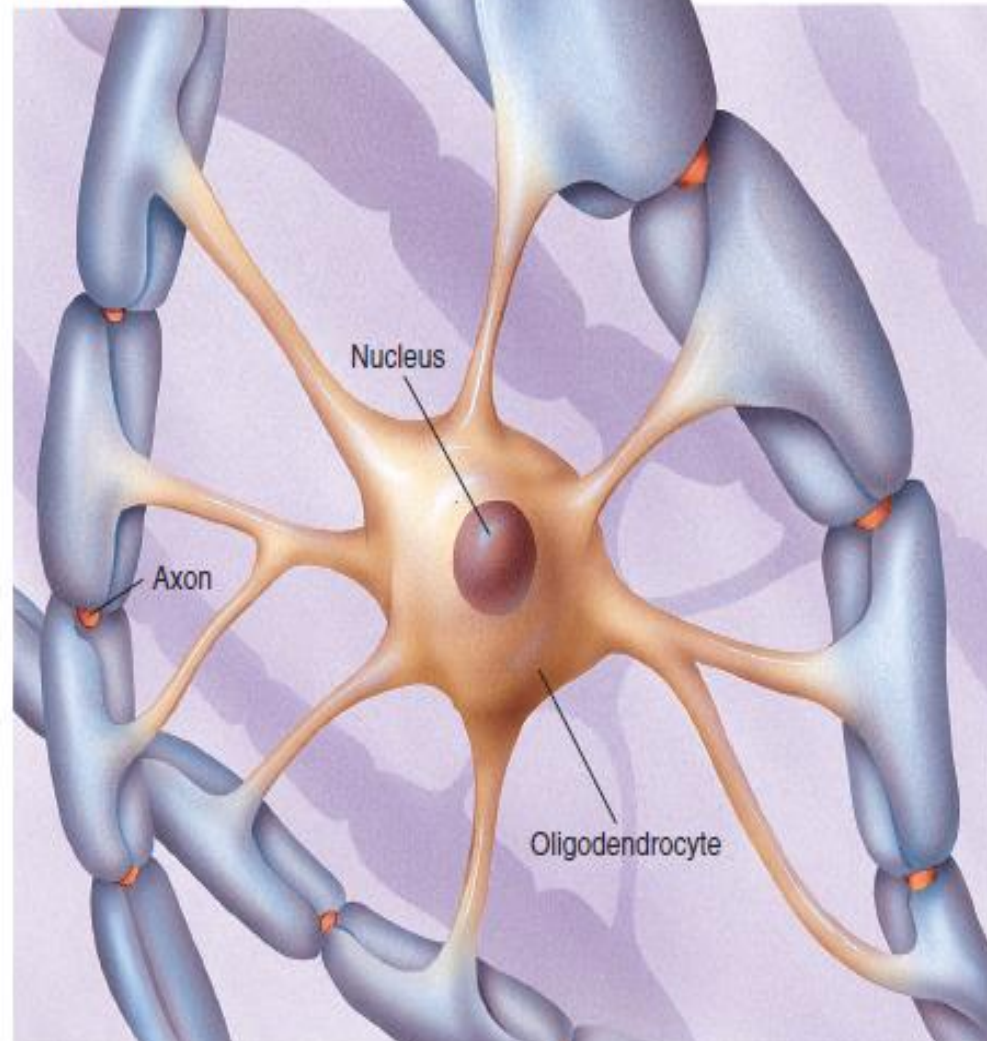
4

Microglia: involved in response to injury/disease, trigger inflammatory responses.

Glial Cells: The Forgotten Cells



Myelination in the Central Nervous System



Myelination in the Peripheral Nervous System



The myelination of CNS axons by oligodendrocyte & myelination of PNS axons by Schwann cells.

Each Schwann cell makes-up 1 myelin segment.

Each oligodendrocyte gives a number of myelin segments.

Glial Cells: The Forgotten Cells



Terminology

	CNS	PNS
Myelin-providing glia	Oligodendrocytes	Schwann cells
Clusters of cell bodies	Nuclei (singular nucleus)	Ganglia (singular ganglion)
Bundles of axons	Tracts	Nerves

Neuroanatomical Techniques



Techniques used to view neurons.

- 1. Golgi stain: allows visualization of individual neurons, used when only overall shape of neuron is of interest.**
 - Italian physician discovered that silver chromate produced by chemical reaction of two substances found their way to some of the neurons in the sample and stained them black.
- 2. Nissl stain: – selectively stains cell bodies**
 - uses a dye called Cresyl violet which penetrates all cells, used to estimate no. of cell bodies in an area by counting no. of stained dots.
- 3. Electron microscopy: provides info about details of neuronal structure**
 - thin slices of tissue coated with an electron absorbing substance that is taken up by different parts of the neuron to different degrees then beam of electrons is passed through the tissue on to a photographic film.

Examples of images produced by these techniques on P.60 in Pinel book.

Neuroanatomical Tracing Techniques



2 types of tracing directions of projections in neurons.

ANTEROGRADE

Anterograde (forward)

**Tracing to where
axons project away
from an area**

RETROGRADE

Retrograde (backward)

**Tracing from where
axons are projecting
into an area**

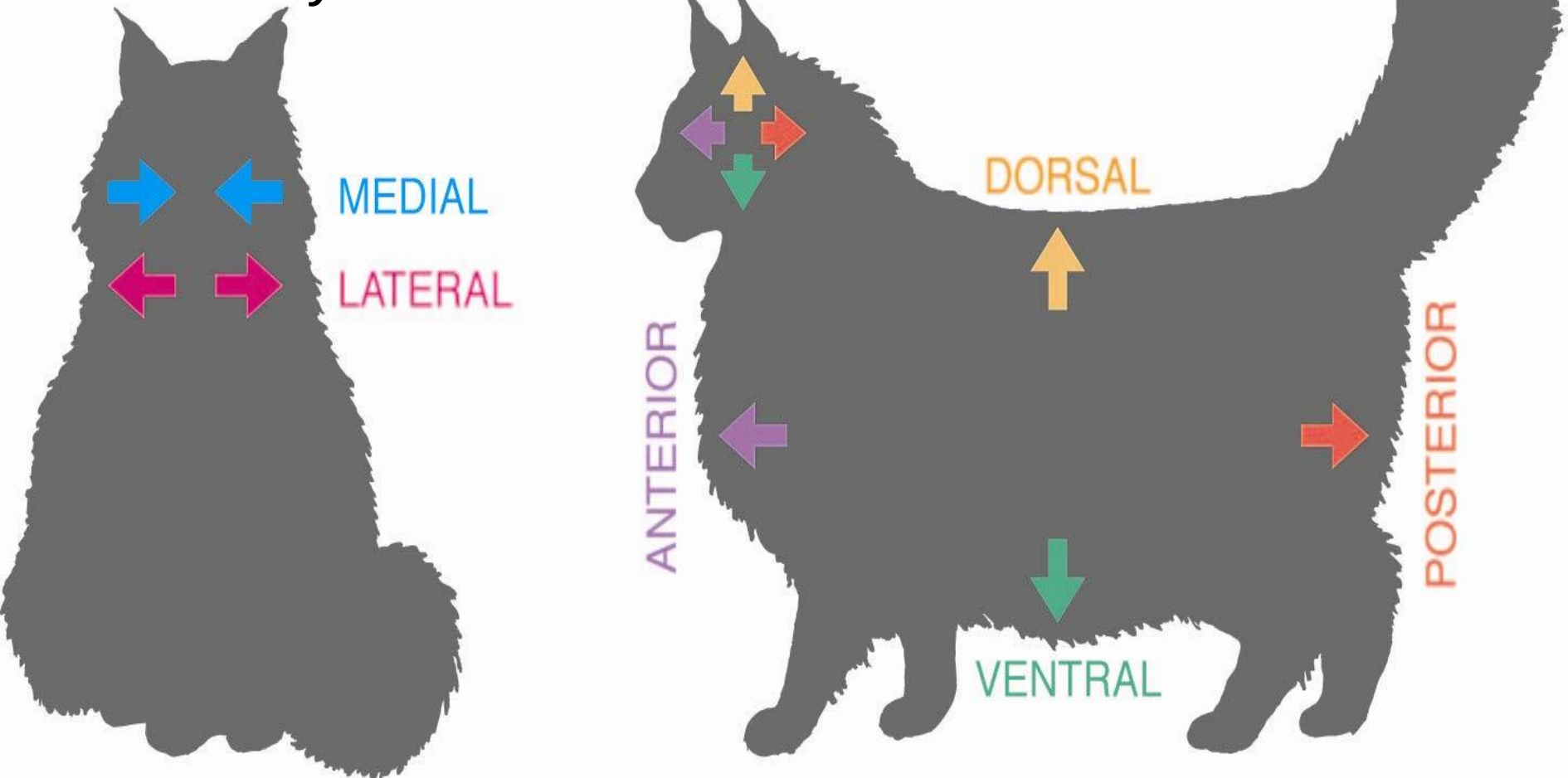
Both work by injecting tracing chemicals taken up by system and transported around.

After a few days, brain is removed, sliced, and treated to reveal the location of the injected chemical.

Directions in the Vertebrate Nervous System

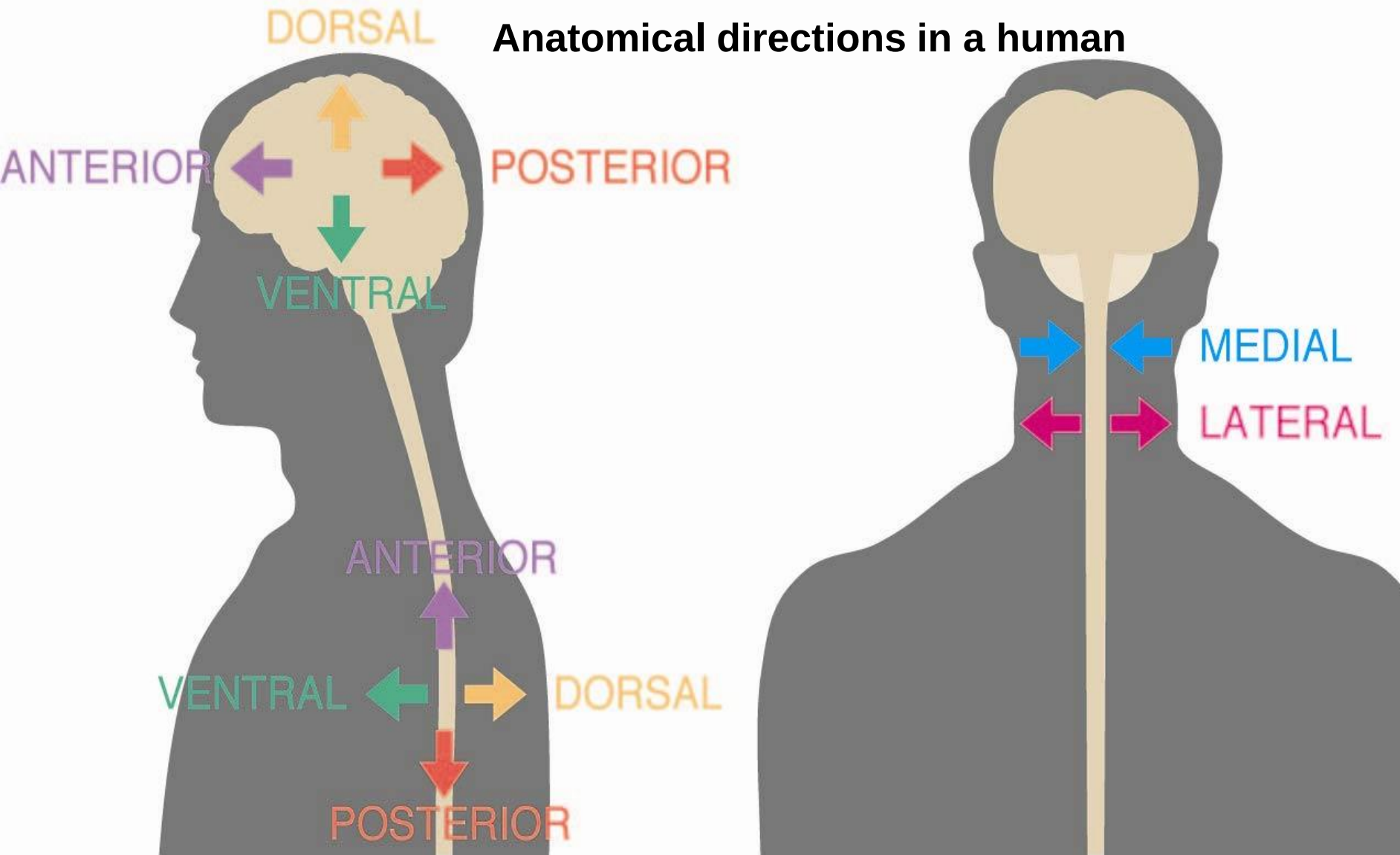


Terminology used to describe directions in the nervous system.



Anatomical directions in a representative vertebrate (cat).

Directions in the Vertebrate Nervous System



Same terms but we walk upright, so directions differ between head & body.

Directions in the Vertebrate Nervous System

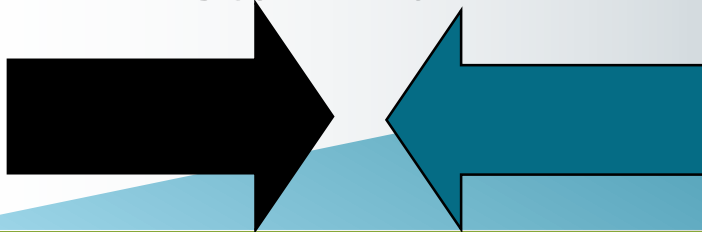


Anatomical directions ignore fact that humans walk upright.

Therefore, top of the head is both “dorsal” (back) and “superior” (top)

Other directions:

- **Proximal – close**
- **Distal – far**

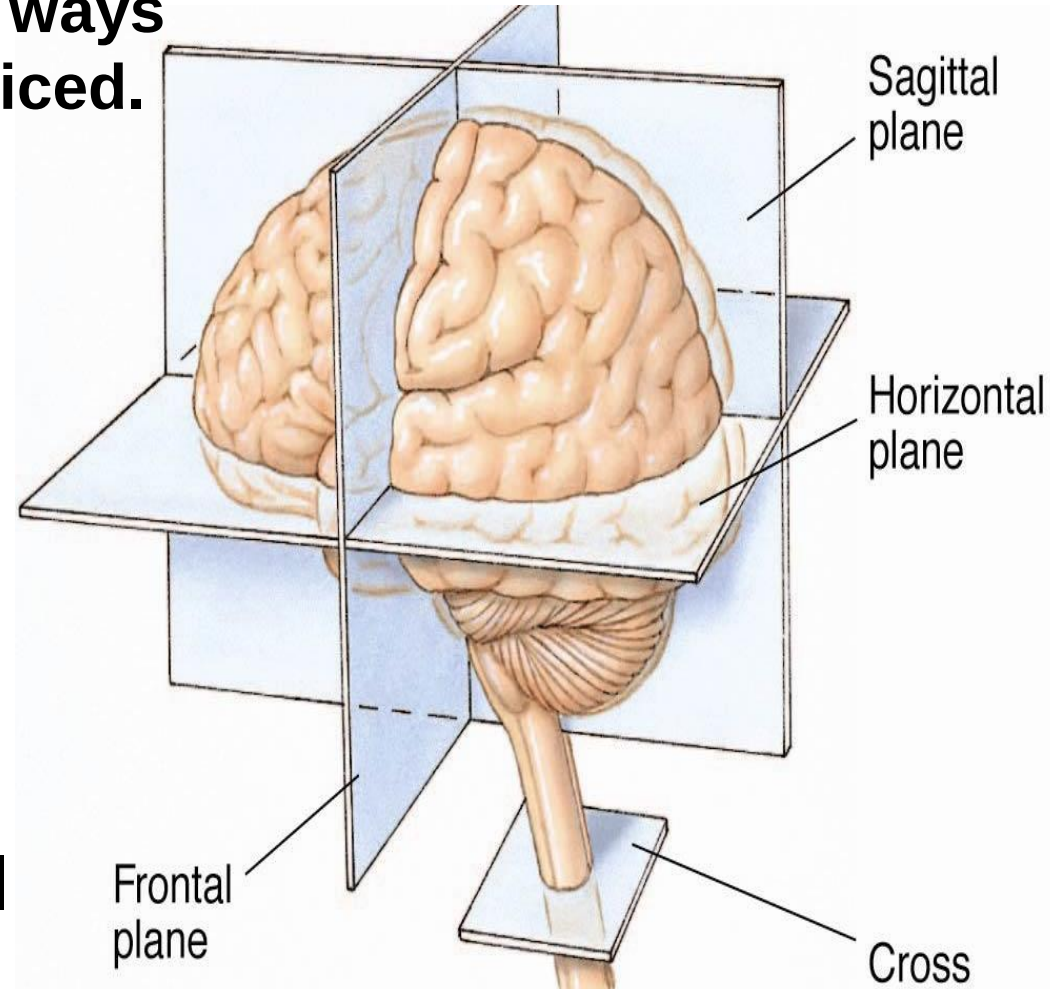


Sections of the Brain



Specific terms to describe ways the brain can be cut or sliced.

- **Horizontal** – slice parallel to the ground
- **Frontal** (coronal) – slicing bread
- **Sagittal** – a midsagittal section separates the left and right halves



Spinal Cord

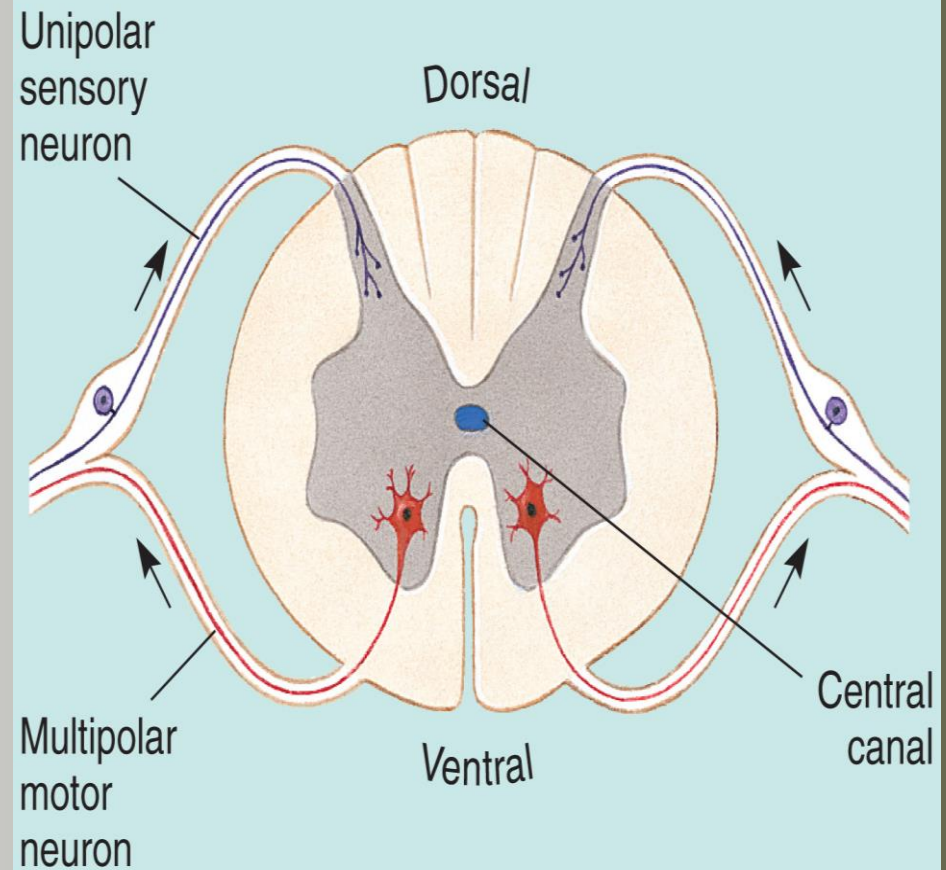
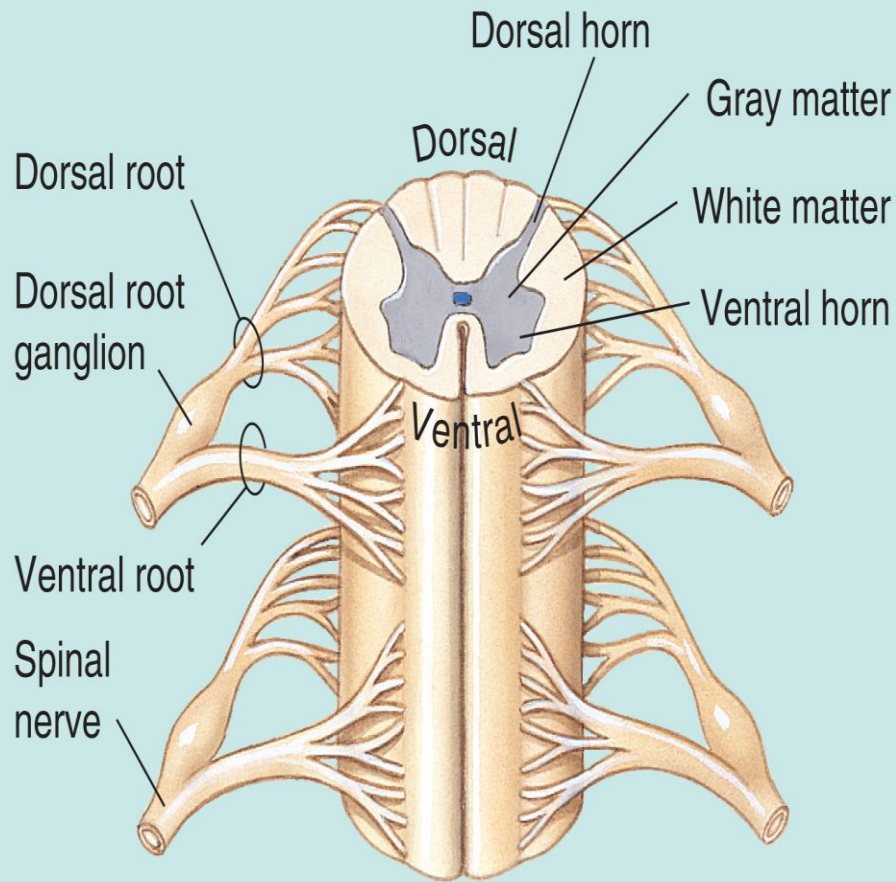


Gray matter – inner component, primarily cell bodies

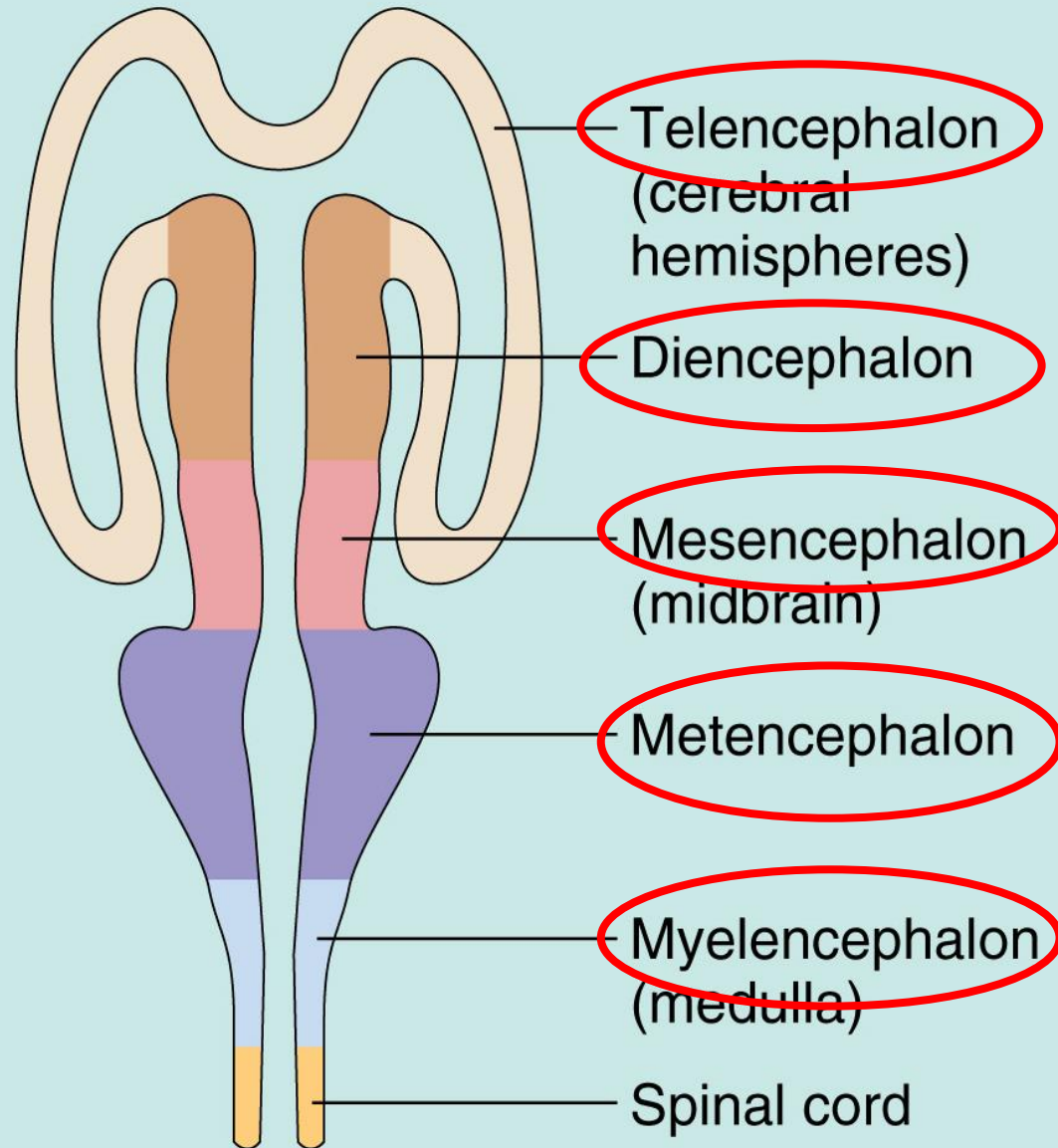
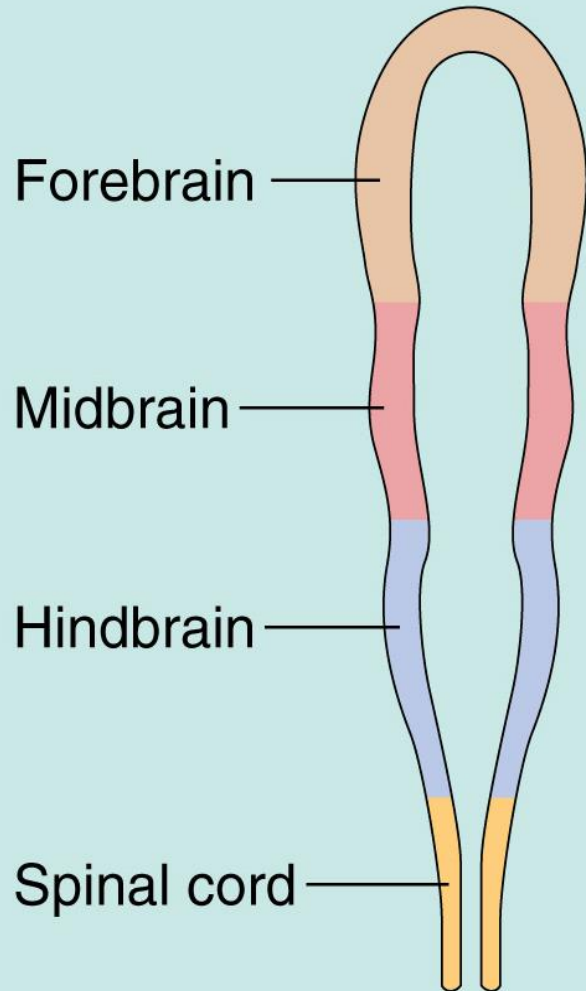
White matter – outer area, mainly myelinated axons

Dorsal – afferent, sensory

Ventral – efferent, motor



Five Major Divisions of the Brain



Five Major Divisions of the Brain



Forebrain

Telencephalon

Diencephalon

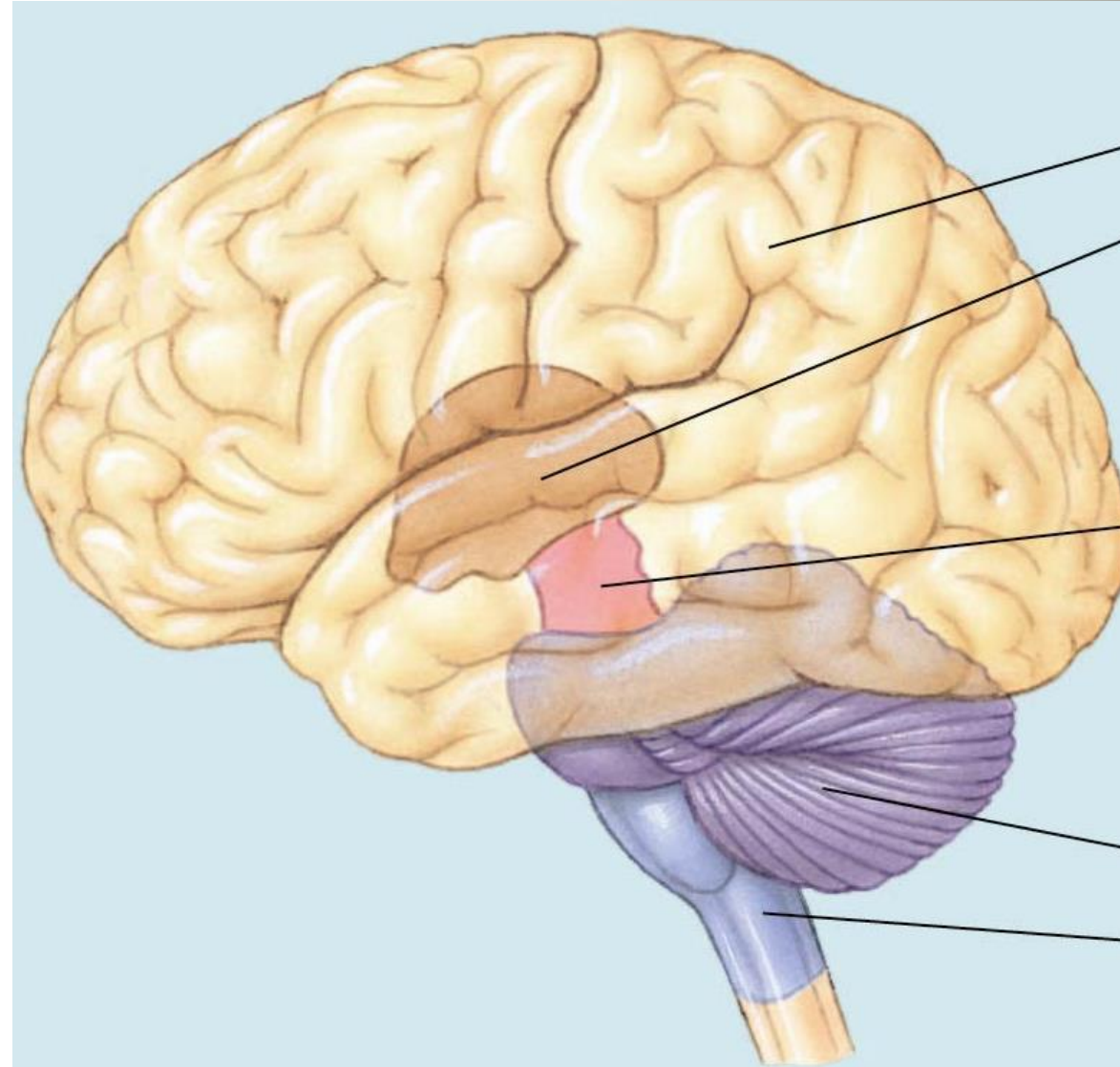
Midbrain

Mesencephalon

Hindbrain

Metencephalon

Myelencephalon



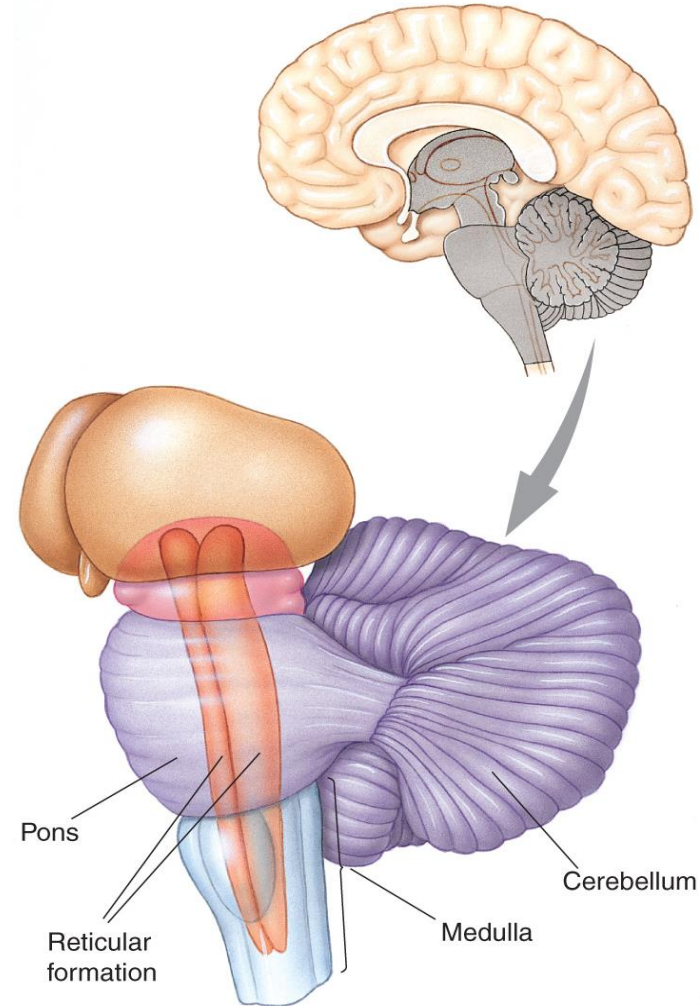
Telencephalon goes through most growth during development.
Other 4 regions may be referred to as the brain stem

Major Structures of the Brain



Myelencephalon = medulla

- Has many tracts to carry signals between brain & body.
- Includes reticular formation: network of ~100 very small nuclei in central core of the brain stem.
- Referred to as reticular activating system because some parts are thought to play role in arousal.
- Other nuclei are involved in sleep, attention, and cardiac reflexes.

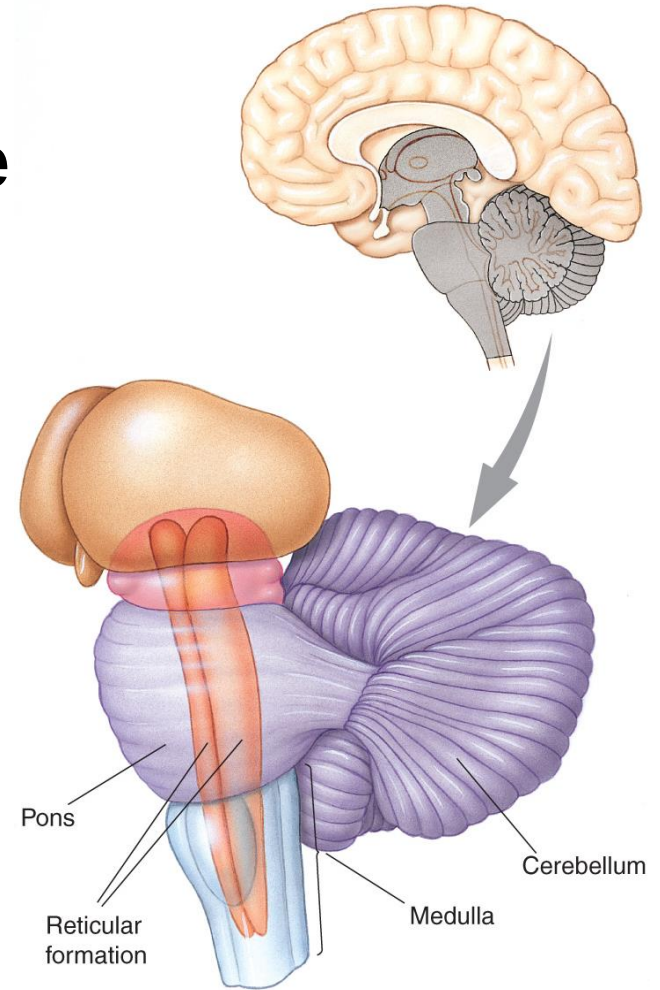


Major Structures of the Brain



Metencephalon

- Many tracts that create a bulge called:
 - The Pons (ventral surface)
- Also has the Cerebellum:
 - Linked to coordination, sensorimotor function and possibly other cognitive functioning.



Major Structures of the Brain



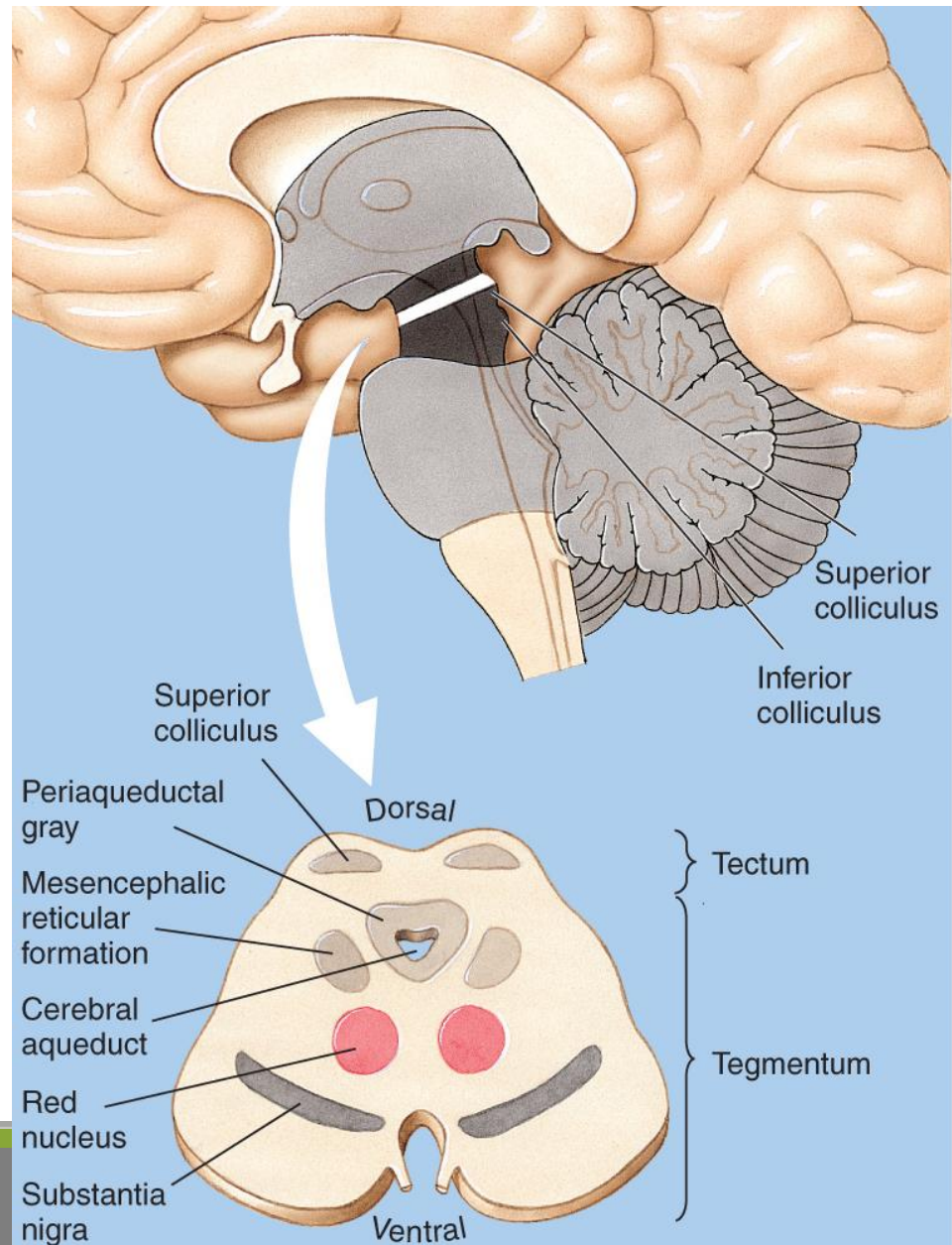
Mesencephalon

Has 2 divisions:

1. Tectum:

- which has inferior (auditory functioning) & superior (visual functioning) colliculi

2. Tegmentum: has periaqueductal gray (mediates pain), substantia nigra & red nucleus (sensorimotor)



Major Structures of the Brain



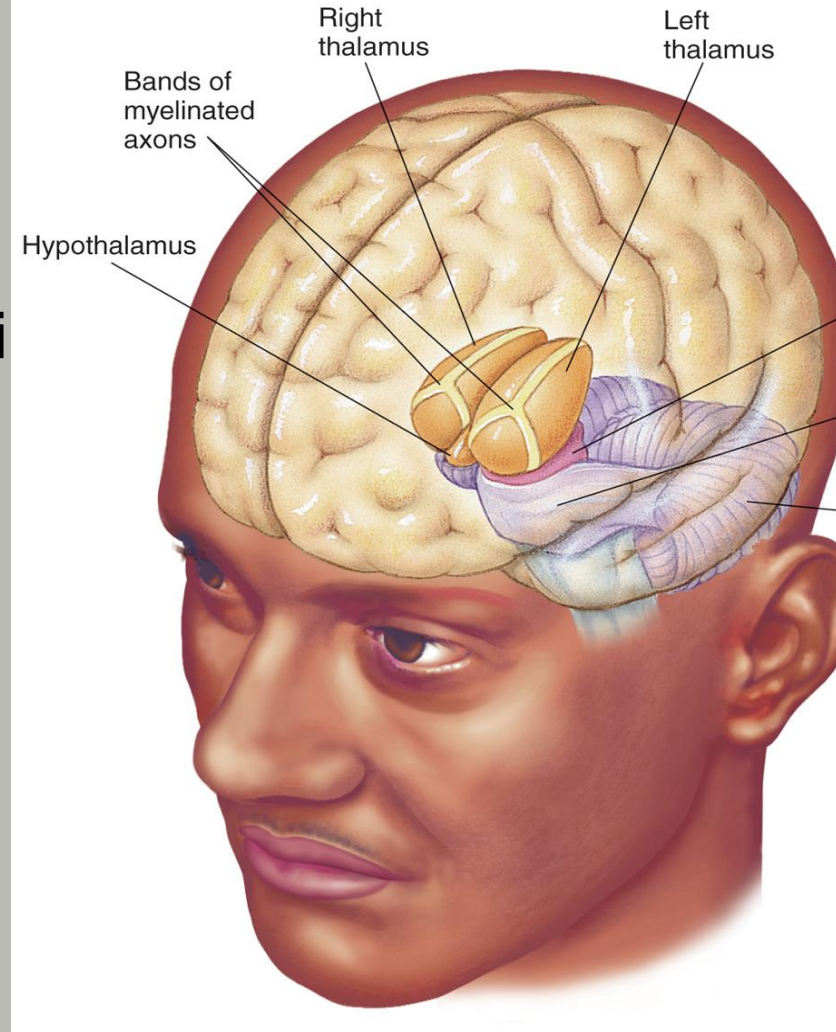
Diencephalon: composed of

1. Thalamus:

- Two lobbed structure joined by mass intermedia.
- Has many different pairs of nuclei that project to cortex.
 - E.g., sensory relay nuclei

2. Hypothalamus

- Plays role in motivation behavior
- Regulates release of hormones



Telencephalon – Cerebral Cortex



The largest division

Involved in the brain's most complex functions

Convolutions serve to increase surface area

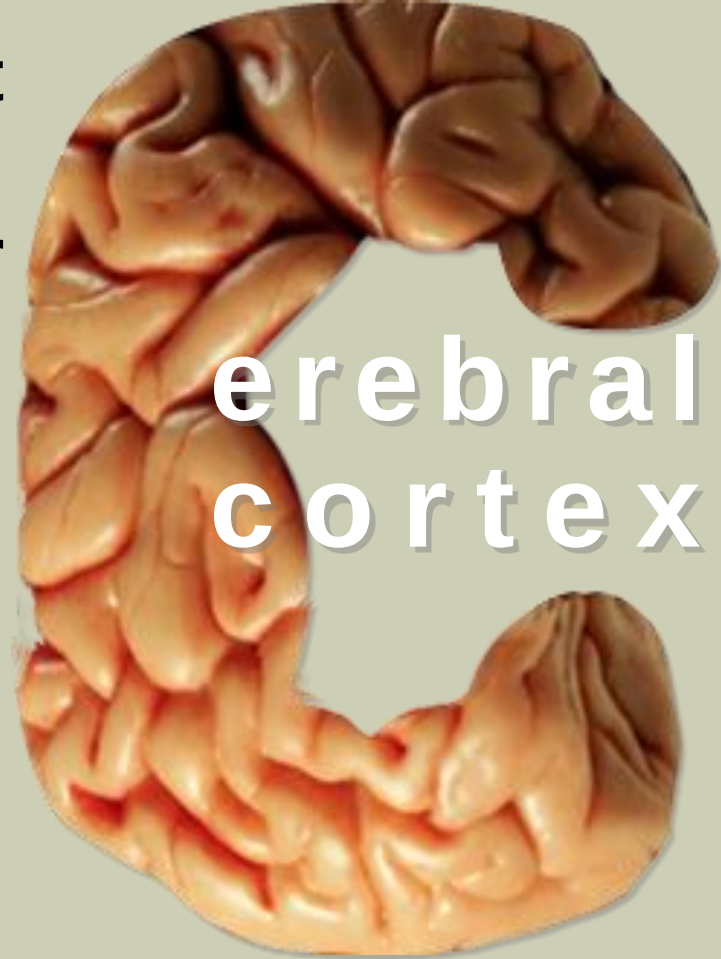
Longitudinal fissure – a groove that separates right and left hemispheres

Corpus callosum – largest hemisphere-connecting tract





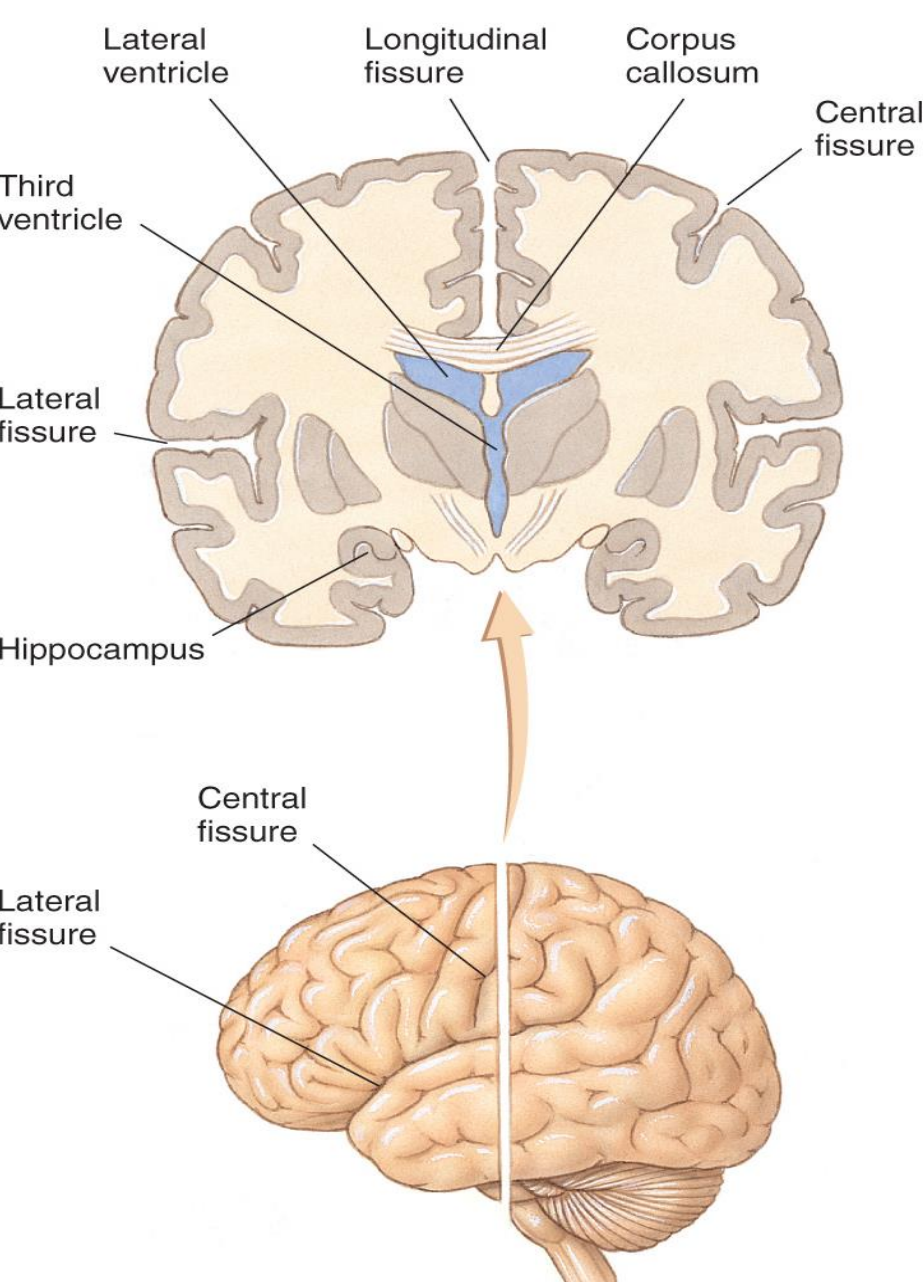
**Outermost part
of forebrain,
responsible for
analyzing
sensory
processing &
higher brain
functions**



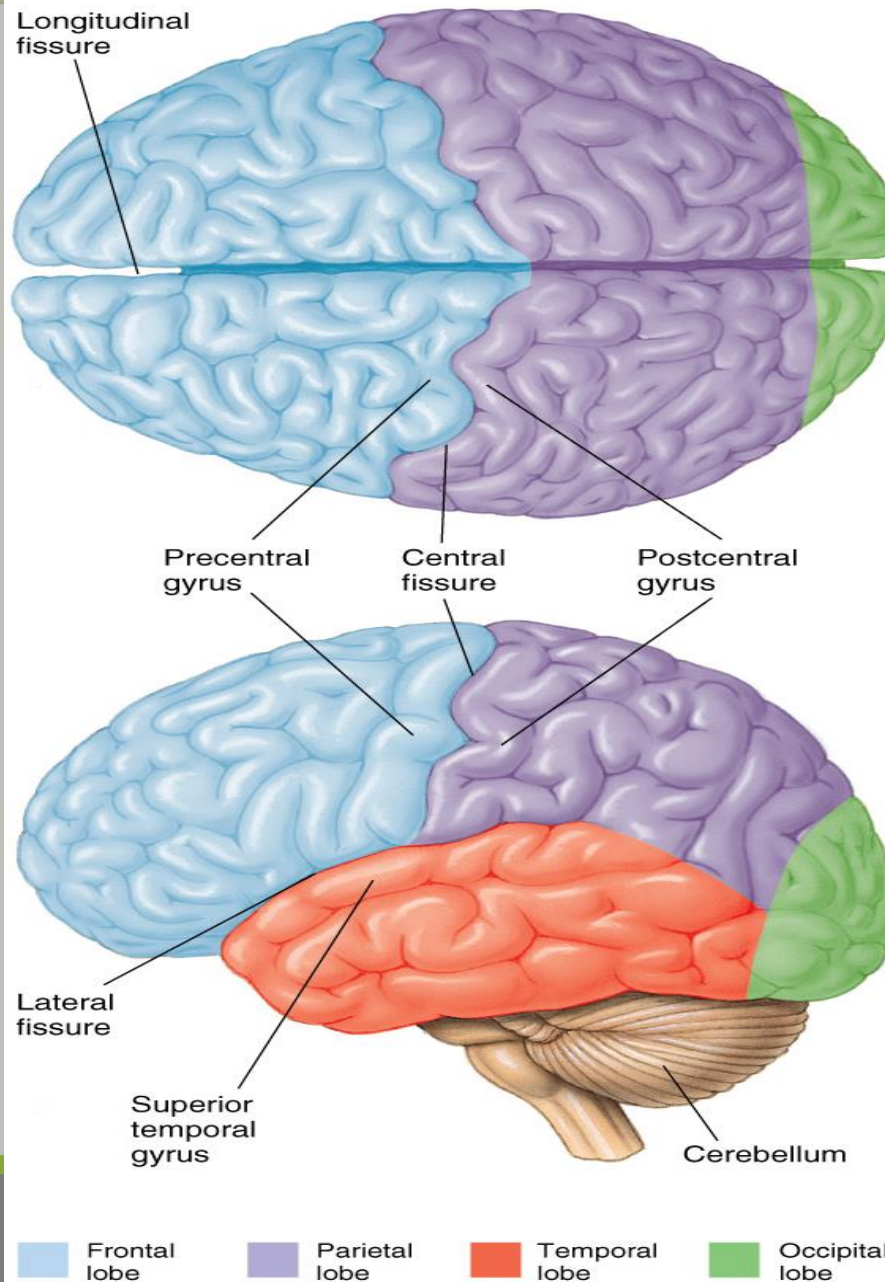
**erebral
cortex**

**The hemispheres of the brain are
covered by the cerebral cortex, which
is mainly composed of small
unmyelinated neurons & known as
Gray matter.**

The major fissures of the human cerebral cortex



The lobes of the cerebral hemisphere



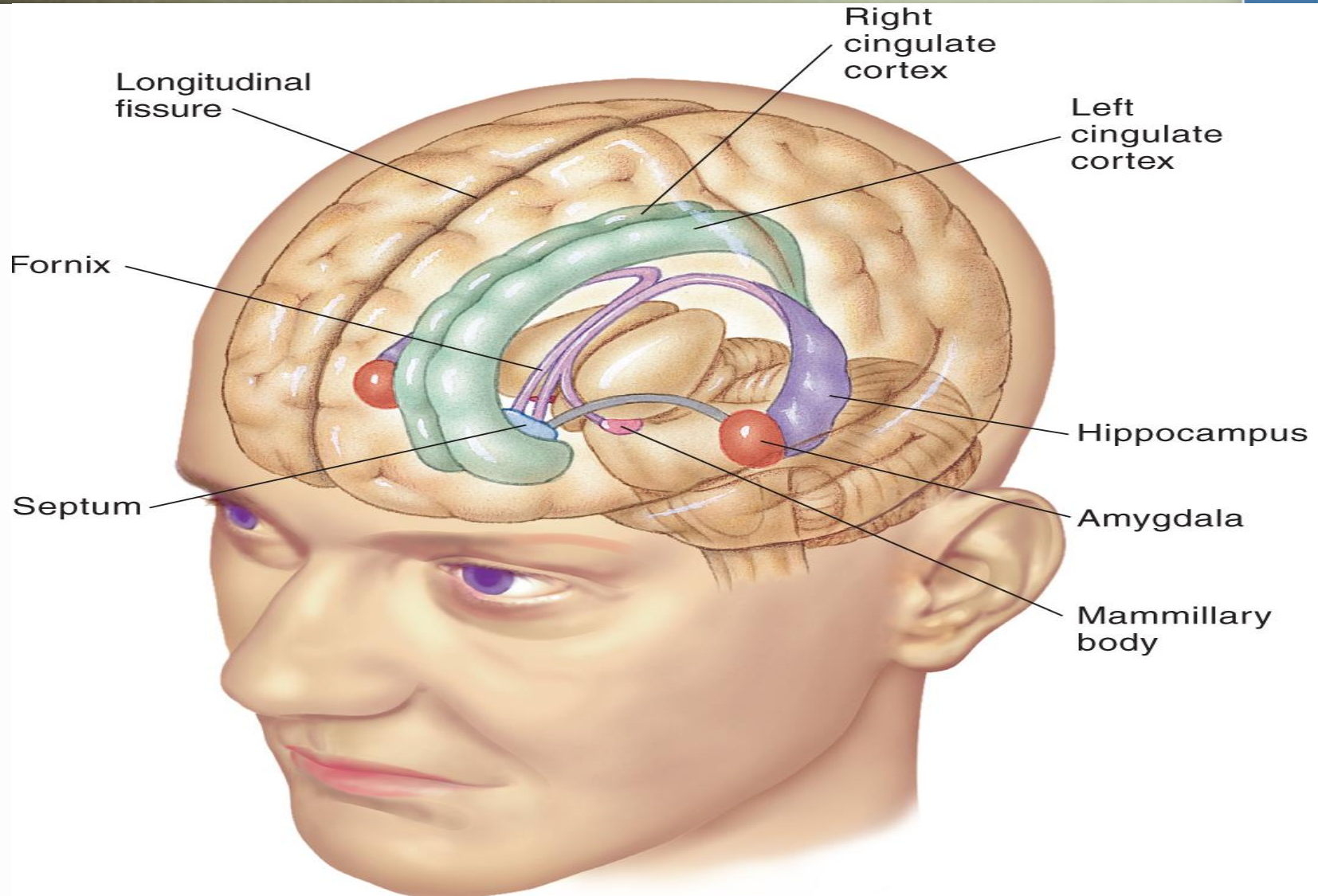
Telencephalon – Subcortical Structures



- In the telencephalon there are several large subcortical nuclear groups considered part of either the limbic or basal ganglia motor system.
- Limbic system:
 - Involved in regulating motivational behaviour
 - A circuit of midline structures that circle the thalamus and include the mammillary bodies, the hippocampus, the amygdala, the fornix, the cingulate cortex, and the septum.
- Basal ganglia motor system
 - Amygdala, striatum (caudate nucleus + putamen), globus pallidus

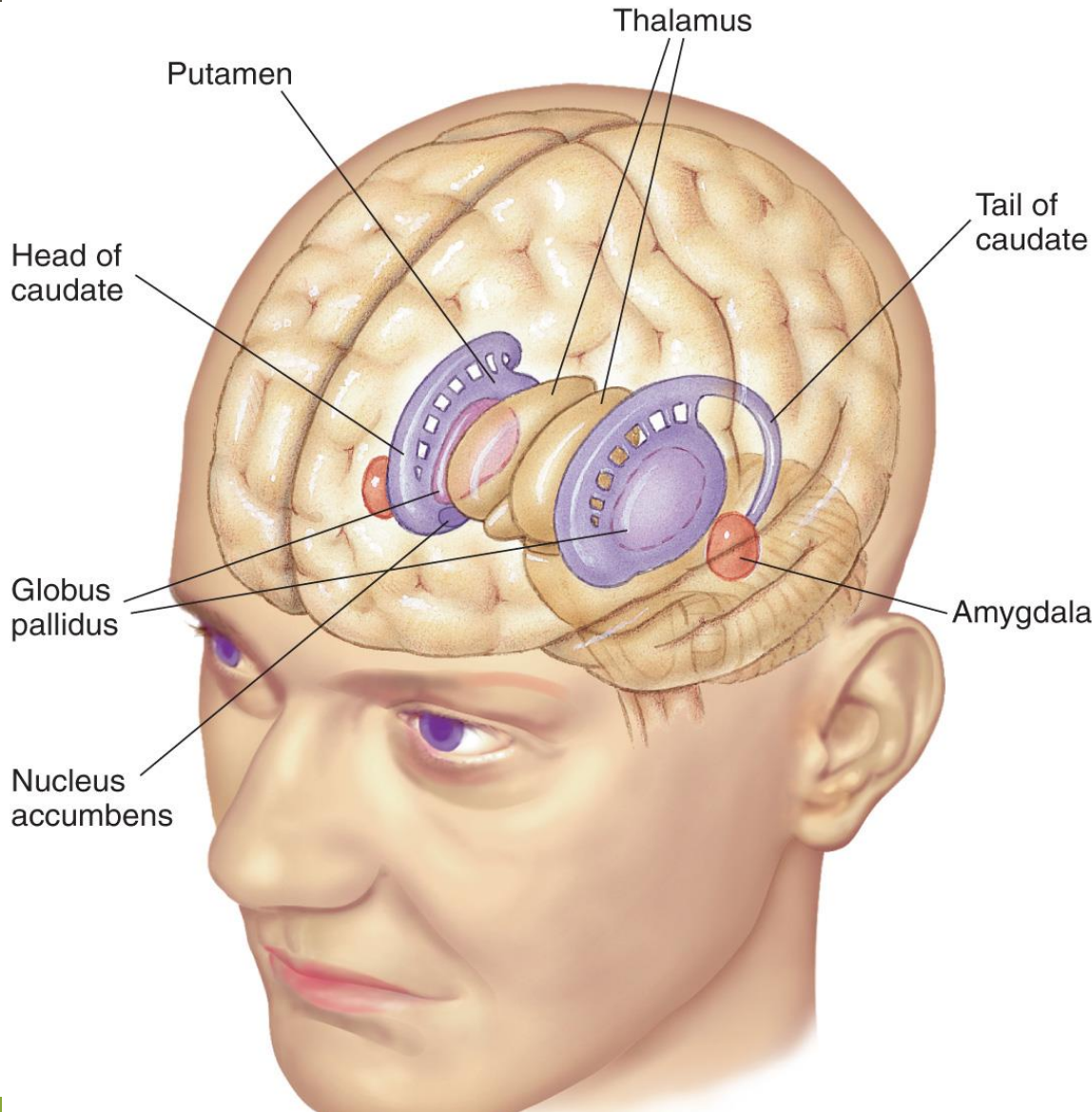


The Limbic System



The major structures of the limbic system: amygdala, hippocampus, cingulate cortex, fornix, septum, and mammillary body

The Basal Ganglia



Structures in the forebrain that help to control movement

- Damage to the basal ganglia contributes to Parkinson's disease.
- The basal ganglia also allow us to perform movements to obtain rewards.

The basal ganglia: amygdala, striatum (caudate plus putamen) and globus pallidus

Summary of major brain structures



Telencephalon	Cerebral cortex	Neocortex Hippocampus
	Major fissures	Central fissure Lateral fissure Longitudinal fissure
	Major gyri	Precentral gyrus Postcentral gyrus Superior temporal gyrus Cingulate gyrus
	Four lobes	Frontal lobe Temporal lobe Parietal lobe Occipital lobe
	Limbic system	Amygdala Hippocampus Fornix Cingulate cortex Septum Mammillary bodies
	Basal ganglia	Amygdala Caudate } Striatum Putamen } Globus pallidus
	Cerebral commissures	Corpus callosum

Diencephalon	Thalamus	Massa intermedia Lateral geniculate nuclei Medial geniculate nuclei Ventral posterior nuclei
	Hypothalamus	Mammillary bodies
	Optic chiasm	
	Pituitary gland	
Mesencephalon	Tectum	Superior colliculi Inferior colliculi
	Tegmentum	Reticular formation Cerebral aqueduct Periaqueductal gray Substantia nigra Red nucleus
Metencephalon	Reticular formation Pons Cerebellum	
Myelencephalon or Medulla	Reticular formation	

Axon Growth and Synapse Formation



- How do axons develop, how are synapses formed, and what happens when neurons die?
- When we are created we begin as a zygote (single cell), which divides, then those divisions divide, etc.
- Some cells turn to muscle, some become neurons, etc.
- All differentiated cells make their way to appropriate sites and align to form a structure.
- Cells then establish relations with other cells.
- Neurons do this through 5 phases: induction of neural plate, neural proliferation, migration and aggregation, axon growth and synapse formation, and neuron death and synapse rearrangement.

Axon Growth and Synapse Formation



- **We will focus on last 2 phases:**
 - Axon growth and synapse formation
 - Neuron death and synapse rearrangement.
- **Once migration & aggregation is complete (cells are in appropriate locations/aligned), axons and dendrites begin to grow from them.**
- **But they need to grow toward specific targets relevant to what they need to do.**
- **At the tip of each axon and dendrite is a growth cone which has fingerlike cytoplasmic extensions that extend and retracts to find the correct route.**
- **Most do end up reaching their correct target.**

Axon Growth and Synapse Formation



Chemoaffinity hypothesis:

- Suggests each postsynaptic surface releases specific chemical that attracts a growing neuron.
- However, this fails to explain why axons follow the same circuitous routes to reach their target in every member of a species rather than just growing directly to it.
- Revised hypothesis suggests growth cones may be influenced by series of chemicals along the way.

Axon Growth and Synapse Formation



- These guidance molecules are not the only signals to help axons grow - other signals come from adjacent cones.
- The first growth cones to travel along a route are pioneer growth cones.
- They follow the correct route by interacting with guidance molecules.
- Then other growth cones follow the route that has already been set out by the pioneers.

Synapse Formation



- **Once axons reach relevant site, they must establish a pattern of appropriate synapses.**
- **Coordination of 2 neurons is required to create a synapse.**
- **Formation of new synapses also requires presence of glial cells:**
 - **Because developing neurons requires a high degree of cholesterol which is supplied by the astrocytes.**



Synapse Formation



- **Glial cells also thought to play a role in processing, transferring, and storing information supplied by neurons.**
- **Research is examining exchange of chemical signals between pre and postsynaptic neurons.**
- **A variety of signals act on developing neurons.**
- **Any synapses that do not function appropriately tend to be eliminated.**



Neuron Death and Synapse Rearrangement



- ~50% more neurons than are needed are produced – so neuron death is normal.
- Some neurons die because they have fulfilled their function.
- Some neurons die due to failure to compete for chemicals provided by targets:
 - The more targets, the fewer cell deaths
 - Destroying some cells increases survival rate of remaining cells
 - Increasing number of innervating axons decreases the proportion that survives

Life-Preserving Chemicals

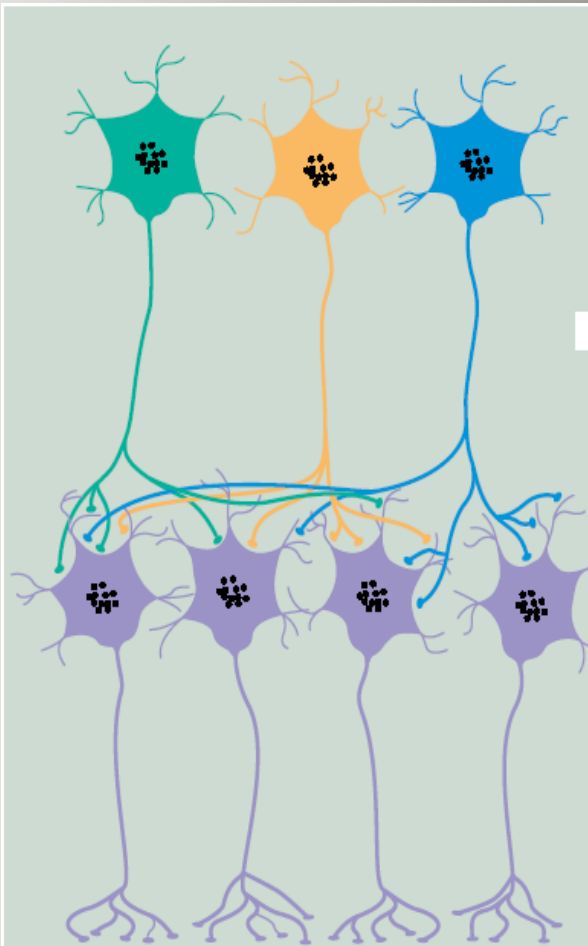


- One type of chemical is called **Neurotrophins** – promote growth and survival of neurons, guide axons, stimulate synaptogenesis.
 - It has a Nerve growth factor (NGF)
- Cell death can be passive (**necrosis**) and active (**apoptosis – genetic programming inside neuron triggers it to die**)
- Apoptosis is safer than necrosis – because it does not promote inflammation

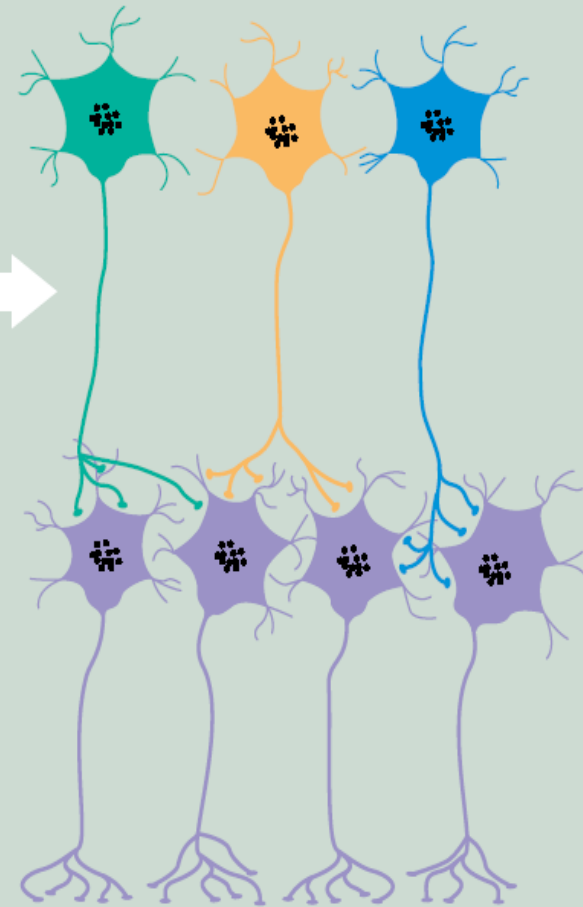
Life-Preserving Chemicals



- **Neurons failing to establish correct connections are likely to die.**
- **Space left after apoptosis is filled by sprouting axon terminals of surviving neurons**
- **Ultimately leads to increased selectivity of transmission**



A diffuse pattern of synaptic contact is characteristic of early stages of development.



A more focused pattern of synaptic contact is present after synapse rearrangement.



Human brain develops slower than other species.

What happens to our brain after we are born.

Postnatal growth is a consequence of:

- Synaptogenesis
- Myelination – sensory areas and then motor areas. Myelination of prefrontal cortex continues into adolescence
- Increased dendritic branches
- Overproduction of synapses may underlie the greater plasticity of the young brain





Development of the Prefrontal Cortex

- **Goes through the longest period of development.**
- **Believed to underlie age-related changes in cognitive function.**
- **No single theory explains the function of this area.**
- **Prefrontal cortex plays a role in working memory, planning and carrying out sequences of actions, and inhibiting inappropriate responses, rules for social behavior.**

Effects of Experience on the Early Development, Maintenance, and Reorganisation of Neural Circuits



- **Neurodevelopment occurs through interactions between neurons & environment:**
 - **Environment = all structures/events inside and outside the organism that can affect the neuron.**
- **Permissive experiences: those that are necessary for information in genetic programs to be manifested**
- **Instructive experiences: those that contribute to the direction of development**

Effects of Experience on the Early Development, Maintenance, and Reorganisation of Neural Circuits



- **Effects of experience on development are time-dependent:**
 - **Critical period:**
 - **Has to happen within certain time**
 - **Sensitive period:**
 - **Can effect outside certain time**
- **If a neural circuit in the brain is not used once it is formed then it will not survive and function normally.**

Early Studies of Experience & Neurodevelopment



- **Early visual deprivation**

- Rats brought up in darkness were found to have fewer synapses and dendrites in primary visual cortex than normally reared rats, and as adults they had poor depth and pattern vision.

- **Enriched environment**

- Rats brought up in complex group cages had:
 - Thicker cortexes
 - Greater dendritic development
 - More synapses per neuron



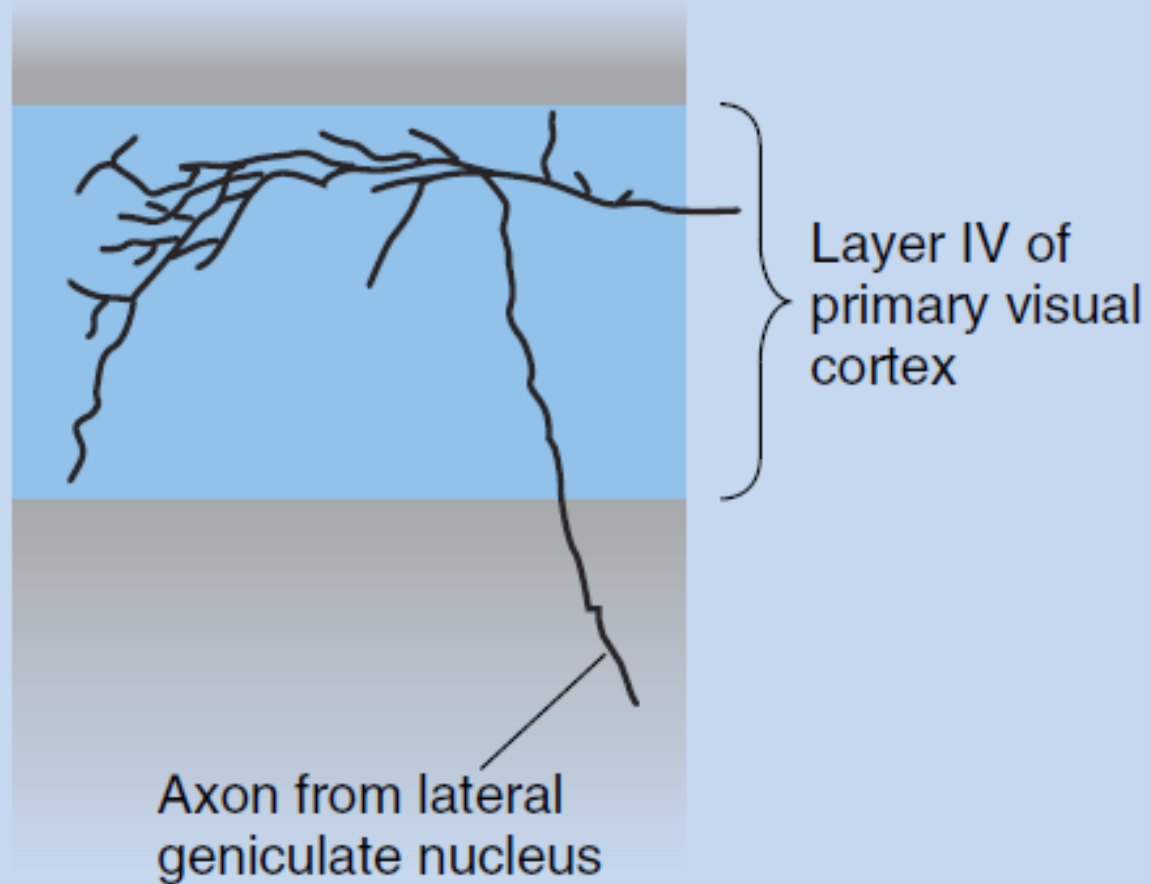
Competitive Nature of Experience and Neurodevelopment



Nondeprived eye



Deprived eye



The effect of a few days of early monocular deprivation on the structure of axons projecting from the lateral geniculate nucleus into layer IV of the primary visual cortex. Axons carrying information from the deprived eye displayed substantially less branching. (Adapted from Antonini & Stryker, 1993.)

Experience Fine-Tunes Neurodevelopment



- Research on experience & neurodevelopment might lead us to think that we should experience everything as soon as possible
- But these studies involve taking something away that would normally be part of our lives not adding anything to it.
- Also, neurons do spontaneously fire and interact with the environment before the nervous system finishes developing.
- These patterns of neural activity then fine-tune the rest of neural development.
- However, the mechanisms for how experience effects development is not fully understood but its thought that experience influences gene expression.



Neuroplasticity in Adults



- The changing or adaptation of neurons
- Neurogenesis (growth of new neurons) seen in olfactory bulbs & hippocampuses of adult mammals'—adult neural stem cells created in the ependymal layer lining in ventricles and adjacent tissues.
- Adult neurogenesis seen in adult rats who lived in enriched environments (had toys, wheels to run on, & company of other rats).
 - They produced 60% more new hippocampal neurons than adult rats living in non enriched environments.
- Enriched environments and exercise can promote neurogenesis

Effects of Experience on the Reorganization of the Adult Cortex



- **Tinnitus** (ringing in the ears) – produces major reorganization of primary auditory cortex
- Adult musicians who play instruments with left hand have an enlarged representation of the hand in the right somatosensory cortex
- Skill training leads to reorganization of motor cortex



Next week...



Neural Conduction and Synaptic transmission

Essential Reading!!!

Biopsychology – Pinel: Chapters 4 & 9